



**Road Development Authority
Japan International Cooperation Agency**

Bridge Repair Manual



October 2017

**The Project for Capacity Development on Bridge Management
In The Democratic Socialist Republic of Sri Lanka**

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Abbreviations

Organizations	
GOSL	Government of Sri Lanka
MHEH	Ministry of Higher Education and Highways
JICA	Japan International Cooperation Agency
RDA	Road Development Authority
Division in RDA	
CD	Construction Division
ES	Engineering Services
M&M	Maintenance and Management
BD	Bridge Designs
P	Planning
PMU	Project Management Unit
RBCU	Rural Bridges Construction Unit
R&D	Research and Development
BM&AU	Bridge Management and Assessment Unit
BAU	Bridge Assessment Unit (1990s)
Position	
DG	Director General
ADG	Additional Director General
DD	Deputy Director
C/P	Counterpart
PD	Provincial Director
CE	Chief Engineer
EE	Executive Engineer
TO	Technical Officer
Manual	
BMM1997	Bridge Maintenance Manual /1997 RDA
RMM1989	Road Maintenance Manual /1989.2 RDA
VRCSG	Visual Road Condition Surveys Guidelines / 2012.6 RDA Planning Division
Others	
BMS	Bridge Management System
OJT	On-the-Job Training
BOQ	Bill of Quantity
RMTF	Road Maintenance Trust Fund
BIV	Bridge Inspection Vehicle
PPE	Personal Protective Equipment
DP	Damage Point
HI	Health Index
II	Importance Index
FOI	Functionally Obsolete Index
LHS	Left Hand Side
RHS	Right Hand Side
BDS	Bridge Database System
BRMS	Bridge Repair and maintenance System
BISS	Bridge Inspection Support System

1. General

1.1 Purpose of the Bridge Repair Manual

Repairs is one of the main components of bridge management cycle.

Its aim is to prevent further development of defects, damages and deterioration and restore to reasonable / satisfactory status.

Purpose of the Bridge Repair Manual is to systematically select appropriate repair methods to each type of defects, damages and deterioration of bridges maintained by the RDA.

1.2 Scope of Application

This manual is intended to serve as a guide for the repair work to be undertaken by RDA.

In particular to act as a guide to select the appropriate repair method suitable for Sri Lanka.

Detailed design method for repair, strengthening, reconstruction and replacement are not included in this manual.

2. In-Depth Investigation

2.1. Purpose of In Depth Investigation

In order to carry out in-depth investigations the status of the structure should be identified specifically and defects quantitatively.

Selecting more items to investigate and methods for collecting data, and arranging more investigation points helps to obtain more detail and accurate information of the structure. However, increase of investigation items and adopting complicated investigation methods lead to more time and cost required for investigations. Also, if inappropriate frequency and coverage of investigation, or inappropriate investigation methods or elements are selected, it becomes difficult to assess the defects, damages and deteriorations.

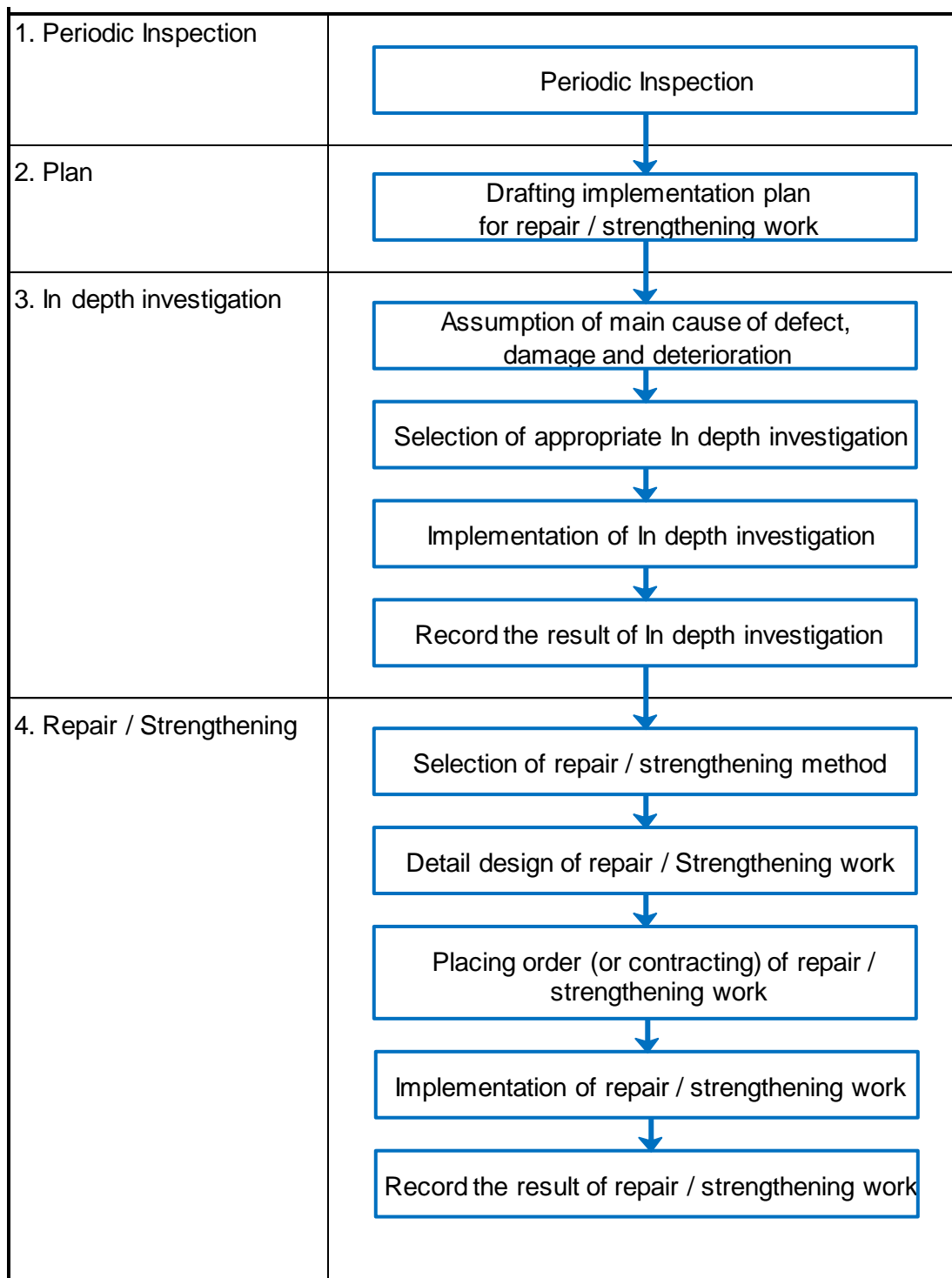
The main purposes of in depth investigation are listed below.

- 1) To understand the cause of defects, damage and deterioration
- 2) To identify the degree and extent of damage / extent of defects, damages and deteriorations and the measures required to rectify them
- 3) To select the appropriate bridge repair method
- 4) To collect data and information necessary for detail design.

2.2. Approaches to In Depth Investigation

The approaches from periodic inspection to Repair / strengthening work are shown in the following flowchart.

Figure 2.1-Flow Chart of In-depth Investigation



2.3 Identification of Cause of Defect, Damage and Deterioration

It is important to identify the cause of defect, damage and deterioration in order to select the in-depth investigation methods.

General relation between type and cause of defect, damage and deterioration for concrete and steel structures are shown in the following Table.

Table 2.1. General Type and Cause of Defect, Damage and Deterioration for Concrete Structures

Cause Type		Carbonation	Chloride	Chemical	Fatigue	Heat or temperature
Status of crack	Crack parallel to reinforcement	○	○			
	Small crack					○
	Grid patterned Mesh-patterned			○	○	○
	Flexural crack Shear crack				○	
	Through crack with equal interval					○
Delamination, Spalling		○	○	○		
Exposure of reinforcing steel		○	○	○		
Rust fluid		○	○	○		
Free lime		○	○	○	○	

Table 2.2. General Type and Cause of Defects Damage and Deterioration For Steel Structure

Cause Type		Chloride	Chemical	Waterproof defect	Cyclic Load / Fatigue	Collision	Support settlement
Degradation of paint, Corrosion		○	○	○			
Crack, Rupture					○	○	○
Falling, Looseness					○	○	○
Deformation					○	○	○

2.4 In Depth Investigation Method and Information to be obtained

In Depth Investigation methods shall be selected properly considering the condition of the structure, based on relevant information and the cause of the defect, damage and deterioration of the structure to be obtained.

Type of In-depth investigation methods and information to be obtained are shown in the following table.

The rough classification of In-Depth Investigations are as follow.

- (a) Non- destructive investigation
- (b) Investigation involving local destruction
- (c) Loading and vibratory loading investigation of existing structures
- (d) Investigation for evaluation of environmental actions

2.4.1 In-depth investigation method and information to be obtained on concrete structures

Table 2.3. In-Depth Investigation methods for concrete structures (Table 1 of 2)

In depth investigation method			Information to be obtained
Non-destructive investigation	Using surface hardness	➤ Using rebound hammer ※	i. Concrete strength
	Using Electromagnetic induction	➤ Using the electrical conductivity and magnetism of steel※ ➤ Using the electromagnetic induction of concrete	i. Locations and diameters of reinforcing steel in concrete and depth of cover ii. State of water content
	Using elastic waves	➤ Hammer tapping ➤ Ultrasonic testing※ ➤ Impact elastic wave method ➤ Acoustic emission testing	i. Concrete quality, e.g. compressive strength and modulus of elasticity ii. Depth of crack on concrete iii. Delamination, peeling and voids in concrete iv. Dimensions of members such as the thickness of concrete v. Grouting in sheath (Prestressed concrete structures)
	Using electromagnetic waves	➤ X-ray method ➤ Electromagnetic radar method※ ➤ Infra-red devices (thermography method)	i. Locations and diameters of steel in concrete and concrete cover ii. Delamination, peeling and voids in concrete iii. Distribution of cracks in concrete iv. Grouting in sheath (Prestressed concrete structures)
	Electrochemical method	➤ Half-cell potential method※ ➤ Polarization resistance method ➤ Four electrodes method	i. Tendency of Corrosion of reinforcement in concrete ii. Rate of corrosion of reinforcement in concrete iii. Electric resistance of concrete
	➤ Using optical fiber scope		i. Internal conditions of concrete ii. Grouting in sheath (Prestressed concrete structures)

Note :

※Refer to attachment.5

Table 2.4 In-Depth Investigation methods for concrete structures (Table 2 of 2)

In depth investigation method		Information to be obtained
Investigation involving local destruction	<ul style="list-style-type: none"> ➤ Core sampling※ ➤ Collection of drilled powder produced while drilling a hole in concrete ➤ Chipping ➤ Sampling steel 	<ul style="list-style-type: none"> i. Crack depth ii. Compressive strength, tensile strength and elastic modulus of concrete (loading tests) iii. Carbonation depth of concrete iv. Analysis of concrete (chemical analysis, fluorescence X-ray analysis, X-ray analysis, thermal analysis, optical microscope, polarization microscope, scanning electron microscope and EPMA) v. Conditions of chloride ions (concentrations of chloride ions and distribution of concentrations) vi. Analysis of mix proportions vii. Released expansion and residual expansion of concrete viii. Air and water permeability of concrete ix. Pore size distribution x. Air void distribution in concrete xi. State of corrosion of reinforcement (by chipping) xii. Tensile strength of reinforcement (by sampling reinforcement)

Note :

※Refer to attachment.5

2.4.2 In-Depth Investigation method and information to be obtained on steel structures

Table 2.5. In-Depth Investigation methods for steel structures

In depth investigation method			Information to be obtained
Non-destructive investigation	Outer Damage	Penetrant test	Defect of welding, Status of crack
		Magnetic particle test	Status of crack
		Eddy current test	Status of crack
		Measuring thickness of steel member by using Ultrasonic test, Depth gauge, Micro meter※	Degree of corrosion
	Internal damage	Ultrasonic test	Defect of welding, Internal defect
		Radiographic test	Defect of welding, Internal defect
	Damage of bolt		
		Tapping test	Loosening, Existence of crack
		Ultrasonic test	Existence of crack

Note :

※Refer to attachment.5

2.4.3 In-Depth Investigation method and information to be obtained on concrete and steel structures

Table 2.6. In-Depth Investigation methods for concrete and steel structures

In-Depth Investigation method		Information to be obtained
<p>Loading and vibratory loading investigation of existing structures</p>	<ul style="list-style-type: none"> ➤ Road alignments, driving feeling test ➤ Loading and vibratory loading tests 	<ul style="list-style-type: none"> i. Section stiffness of member (static and dynamic stiffness) ii. Vibration characteristics
<p>Investigation for evaluating environmental actions</p>	<ul style="list-style-type: none"> ➤ Based on existing records ➤ Based on meteorological data ➤ Direct measurement (using sensors, etc.) ➤ Monitoring 	<ul style="list-style-type: none"> i. Meteorological conditions (e.g. temperature, maximum / minimum temperature, humidity, precipitation and insulation) ii. Water supplies (conditions of weathered part of bridge exterior, conditions of water supplies from the ground, waterproof layers and drain facilities) iii. Salt supplies (e.g. amount of air-borne salt, effects of seawater and amount of deicing agents spread) iv. Wind (direction, velocity and frequency) v. Carbon dioxide concentration vi. PH of highly acidic river water vii. Water quality in sewerage facilities viii. Occurrence of acid precipitation and acid fog ix. Alkali supplies x. Loading conditions (vehicles, vibrations, water pressure, etc.) xi. External forces related to disasters (e.g. earthquakes and fires)

3. Bridge Repairs and Strengthening

3.1. Approaches to Selection of Bridge Repair Methods

(1) Performance Requirements

The performance requirements expected from the maintenance process of an ordinary structure includes safety, serviceability, and hazard for third party, an aesthetic appearance and landscape, and durability. The output expected from maintenance is shown in Table 3.1

Table 3.1 Performance Requirements

ITEMS		Performance Requirements
Safety (Structural stability)		It is related to safety against sectional fracture, safety against fatigue fracture and safety with respect to the stability of structure.
Serviceability	Stiffness	It is related to the performance that enables the user of structure to use it comfortably. (e.g. Riding quality)
	Except for stiffness	It is related to the functional requirement of the structure. (e.g. Water- tightness, Permeability, Sound proofing)
Durability		It is related to the resistance of the structure to time based deterioration of performance due to the degradation of members of the structure under intended action.
Hazards for third party		It is related to damage to third parties caused by structures such as the falling of cover concrete lumps or bolts and the noise that is caused while the structure is in service.
Aesthetic appearance and landscape		It is related to the harmonization with the surrounding environment including the effects of stain of rust and cracks due to the deterioration.

(2) Type and Selection of Remedial Measures

The types of remedial measures shall be selected based on the performance of the structure and the level of performance to be achieved after effecting remedial measures. Types of remedial measures to be taken according to performance are shown in Table 3.2.

Table 3.2 Types of Remedial Measures According to Performance

Items		Level of performance to be achieved and type of remedial measure	
		Level at the time of original construction	Level higher than at the time of construction
Safety (Structural stability)		Strengthening	Strengthening
Serviceability	Stiffness	Strengthening	Strengthening
	Except for stiffness	Repair	Repair
Durability		Repair	Repair
Hazards for third party		Repair	Not Applicable
Aesthetic appearance and landscape		Repair	Repair

(3) Selection of Repair Method and Material

Experienced engineer shall select the appropriate repair method and material to each bridge from the repair manual by carefully considering each type of defect, damage and deterioration.

Repair method shall be effective against investigated defects, damage and deterioration and sufficiently durable in principle. Also, it shall restore defected, damaged and deteriorated bridge to the original status.

When damage / degradation is in early stage and / or small in size, repair work is facile and effective. On the other hand, when the defect, damage and deterioration has advanced onto a serious stage, large in size, or arisen due to material characteristics, etc. repair work would not be very effective nor durable and the magnitude of repair and the cost is enormous..

In case, the defect, damage and deterioration is not in a harmful condition structurally and also for the safety of the third party, and the defects are not increasing or progressing slowly based on the results of in depth or periodical inspections, it may be allowed to progress without repair, while monitoring closely.

(4) Detail Design for Repair Work

In case detail design for repair work is necessary, it shall be conducted by subject specialized engineer. The designer shall examine the selection of repair method and materials, structural analysis to ensure safe conditions during repair activity.

Detail design for repair may be omitted when it is obvious that the influence of the repair work to the structural stress is minimum. Reconstruction may need to be considered in such a case if the damage is severe.

(5) Planning the Repair Work

A plan for the repair work shall be prepared in advance of the actual work.

The plan shall include, but not limited to, the amount of work needed, type of repair, material to be used, drawings, inspection sheets, working schedule and rough cost estimates.

Some repair work may require preparation in advance, for example, removing dust from the parts identified for repairs. Also, a plan for preparatory work such as installation of scaffolding to support repair work need to be prepared.

3.2. Classification of minor and major repair

Classification of Minor and Major repair with consideration of technical difficulty and necessary equipment is shown in following tables.

3.2.1 Concrete structure (Superstructure / Substructure)

Table 3.3 Classification of repair method for concrete structure

Classification	Repair / Strengthening Method		
Minor Repair	Repair	Plastering ※1	Used for repair of scaling, spalling (Area < 10m ² , Depth < 30mm)
		Jacket wall / Foot protection	Used for preventing the scour of bridge foundation
		Routing and sealing method	Used for crack repair (Crack width > 1.0mm)
	Preventive	Apply rust Inhibitor on reinforcement	Used for preventing corrosion of reinforcing steel
		Substrate impregnation (Silane)	Used for preventing chloride ion, moisture and air from penetration
		Surface coating	Used for preventing deteriorate factors from penetration
Major Repair	Repair	Epoxy Injection	Used for repair crack (Crack width < 1.0mm)
		Recasting concrete	Used for repair of scaling, spalling (Area > 10m ² , Depth > 30mm)
		Grouting	Used for repair of scaling, spalling (Area > 10m ² , Depth > 30mm) Scour
		Wet and dry mortar spraying	Used for repair of scaling, spalling (Area > 10m ² , Depth > 30mm)
		Pouring / Injection method with form	Used for repair of scaling, spalling (Area > 10m ² , Depth > 30mm)
	Strengthening	Continuous fiber-reinforced sheet bonding	Used for increasing the strength
	Preventive	Sacrificial Anode Material (Attached to reinforcing steel)	Used for protecting from salt damage and carbonation
		Calcium Nitrite / Lithium Nitrite	Used for protecting from salt damage and carbonation

Note

※1 : Refer to attachment1

3.2.2 Steel structure (Superstructure)

Table 3.4 Classification of repair method for steel structure

Classification	Repair / Strengthening Method		
Minor Repair	Repair	Zone painting ※2	Used for recovery of small area surface coating
		Repainting	Used for recovery of large area surface coating
		Replacing lost bolts & nuts	
	Preventive	Anti-corrosion painting system	Used for preventing from corrosion.
Major Repair	Repair	Replacement of steel bridge member	Used for increasing or recovering the strength
		Painting complex structures	Used for recovery of large area surface coating
		Steel Plate Bonding	Used for increasing or recovering the strength
	Strengthening	Continuous Fiber Reinforced Sheet / Plate Bonding	Used for increasing the strength
	Preventive	Introducing stop holes	Used for preventing the stress concentration due to fatigue crack

Note :

※Refer to attachment 3

(1) Foundation

Table 3.5 Classification of repair method for foundation

Classification	Repair / Strengthening Method		
Major Repair	Strengthening	Widening the footing (For spread Foundation)	Used for improving the stability of foundation
		Provision of Additional Piles (For pile foundation)	Used for improving the stability of foundation

(4) Accessories

Table 3.6 Classification of repair method for accessories

Classification	Repair / Strengthening Method	
Minor Repair	Repair	Replacement of Asphalt Sealant of joint
		Replacing damaged hand rail
Major Repair	Repair	Replacement of Bearing / Expansion Joint

(5) Others

Table 3.7 Classification of repair method for others

Classification	Repair / Strengthening Method	
Minor Repair	Preventive	Reducing impact on bridge due to approach settlement by road rehabilitation
	Preventive	Providing approach slabs or prevention of consolidation settlement on approaches

3.3. Selection of repair method

5 kind of flowcharts for selection of applicable repair methods are shown as follows. Repair method should be selected correspond to type, cause and degree of defect, damage and deterioration.

- Repair methods for concrete structure (Except for deck slab)
- Repair methods for concrete structure (Deck slab)
- Repair methods for steel structure
- Repair methods for foundation
- Repair methods for accessories

(1) Selection of repair method for concrete structure (Except for deck slab)

Figure.3.1 Type of defects, damages and deterioration: Spalling, Delamination (Except Deck Slab)

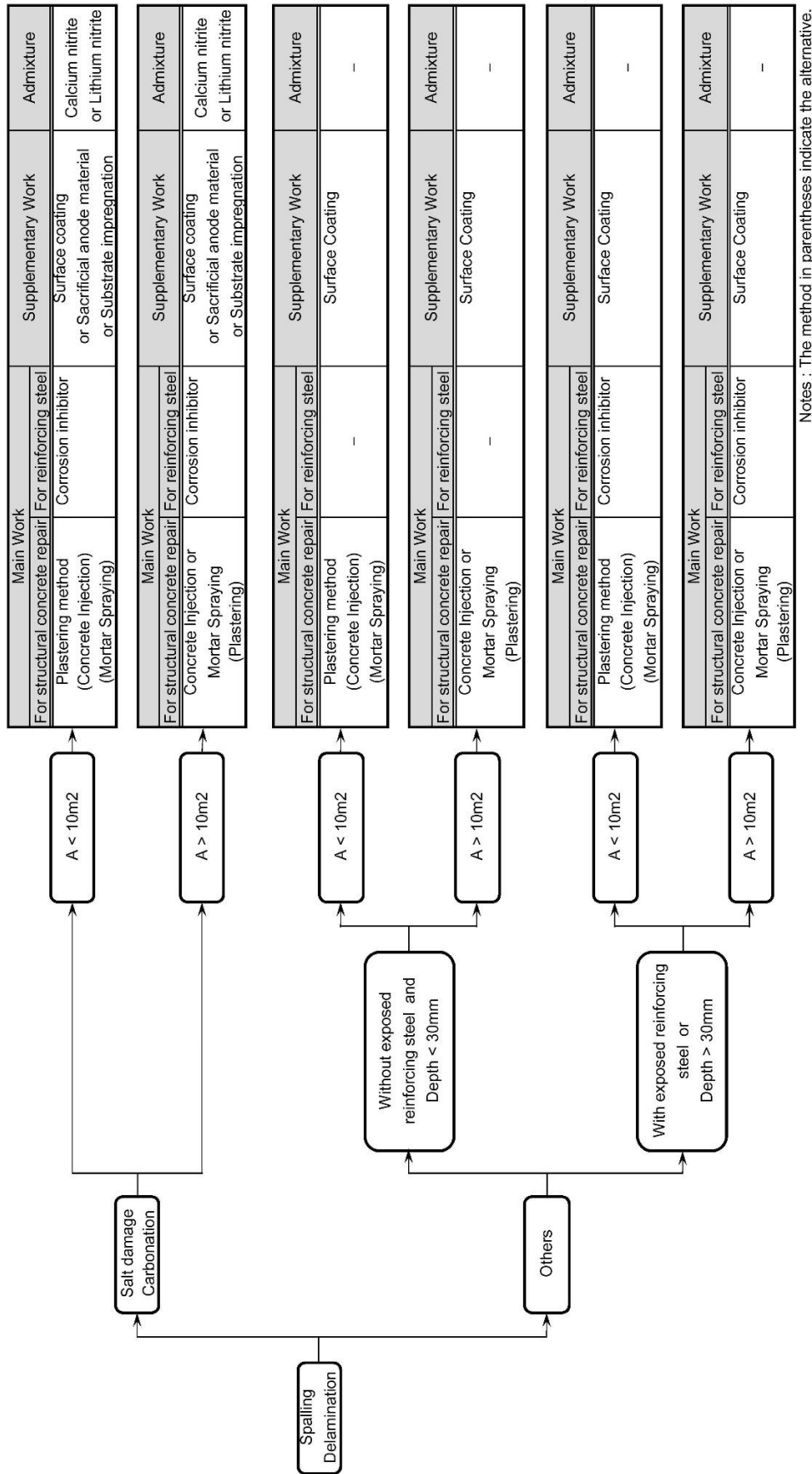
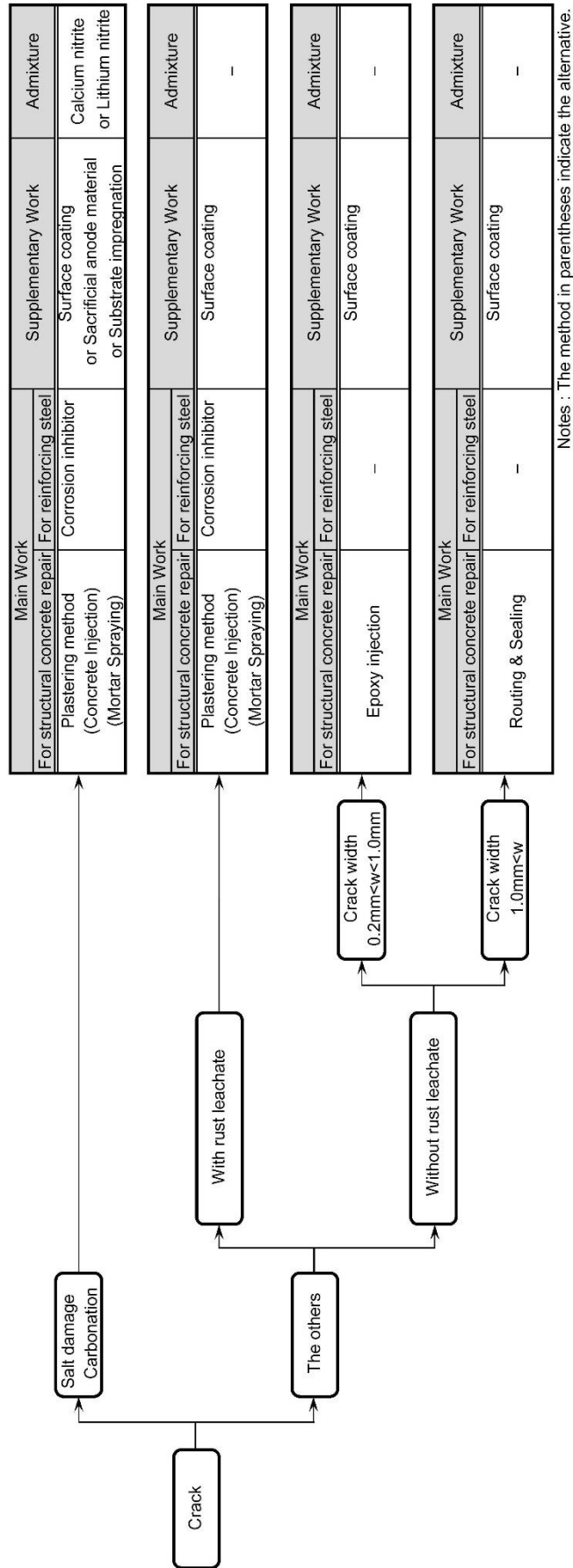


Figure 3.2 Type of defects, damages and deterioration: Crack (Concrete Structures)



(2) Selection of repair method for concrete structure (deck slab)

Figure 3.3 Type of defects, damages and deterioration: Spalling, Delamination

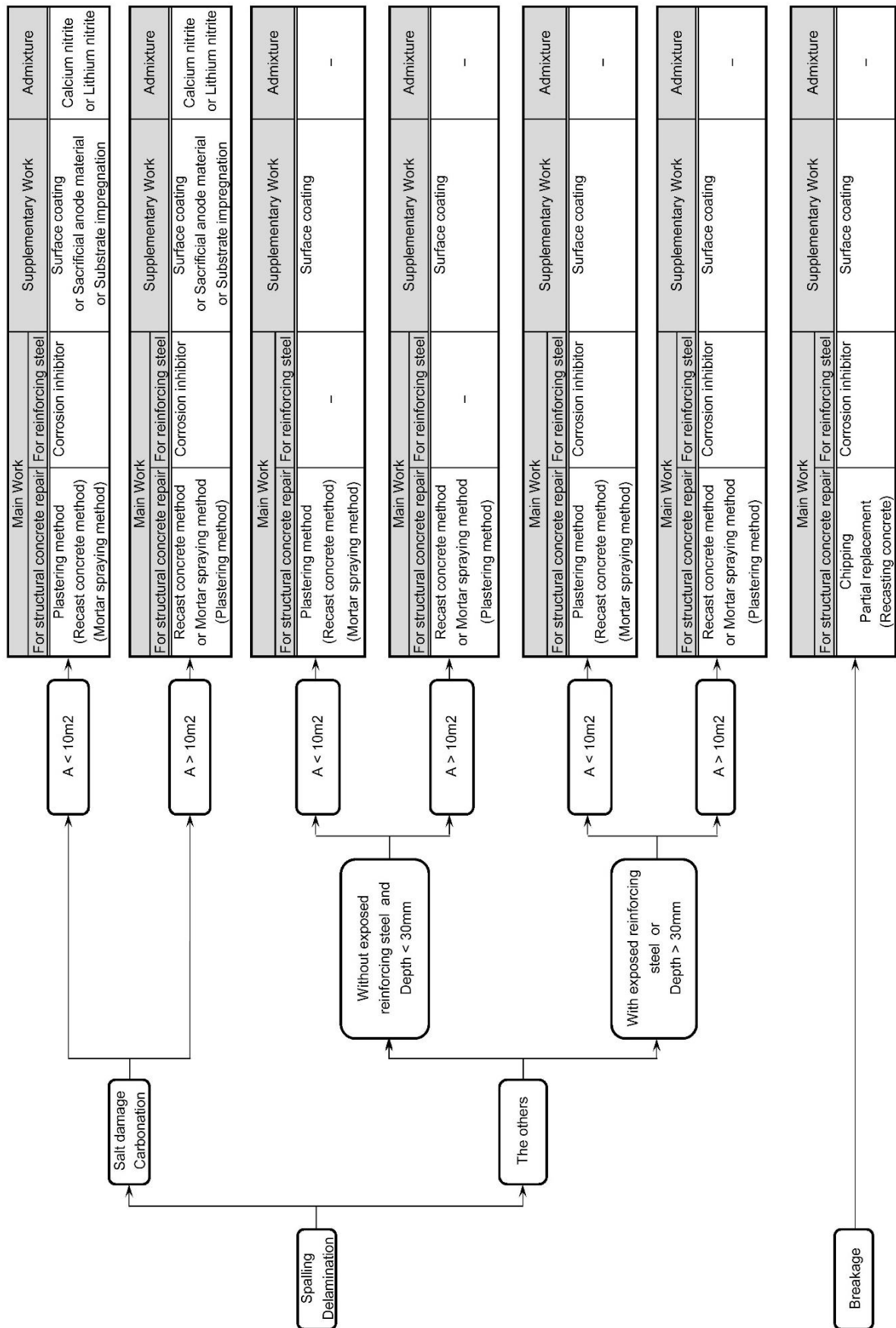
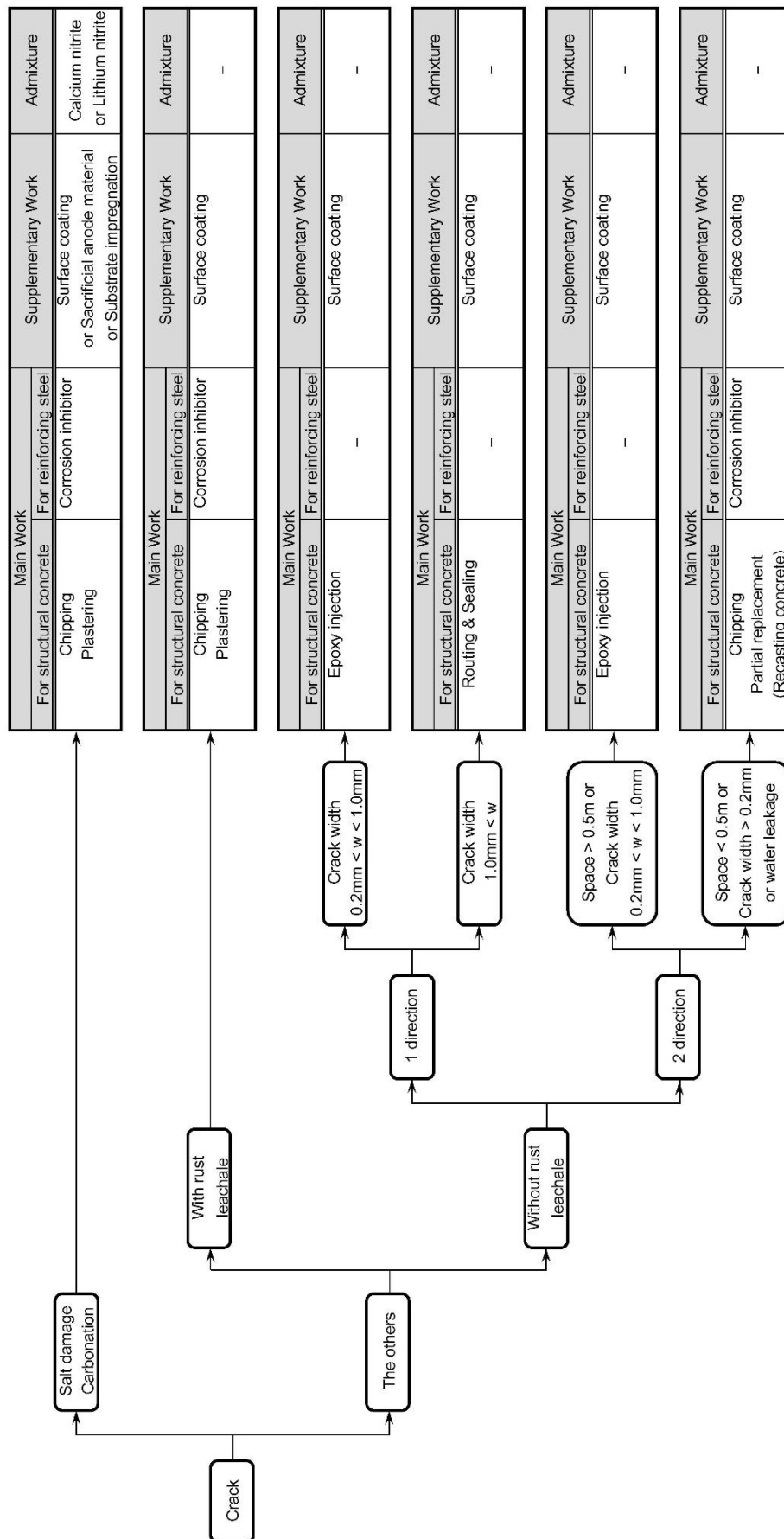


Figure 3.4 Type of defects, damages and deterioration: Crack (RC Deck Slab)



Notes : The method in parentheses indicate the alternative.

(3) Selection of repair method for steel structure

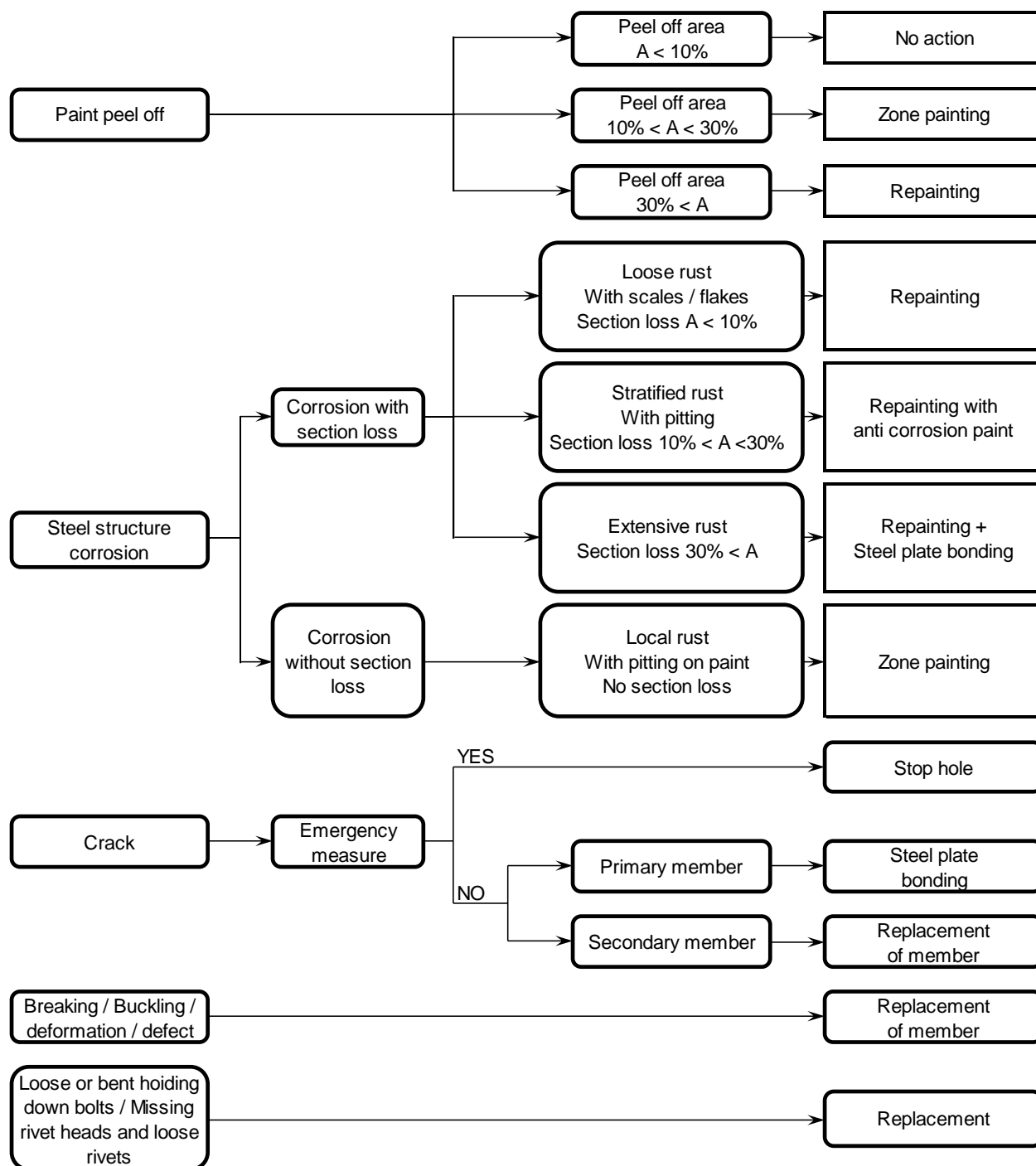


Figure 3.5 Selection of repair method for steel member

(4) Selection of repair method for foundation

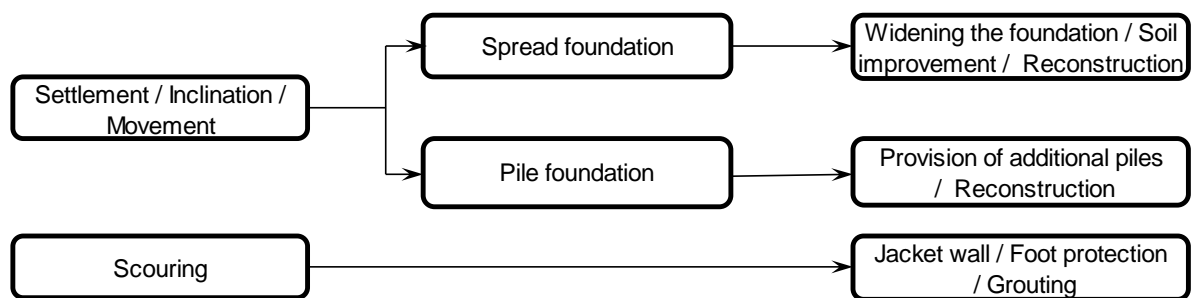


Figure 3.6 Selection of repair method for foundation

(5) Selection of repair method for accessories (Bearing and Expansion joint)

Bearing

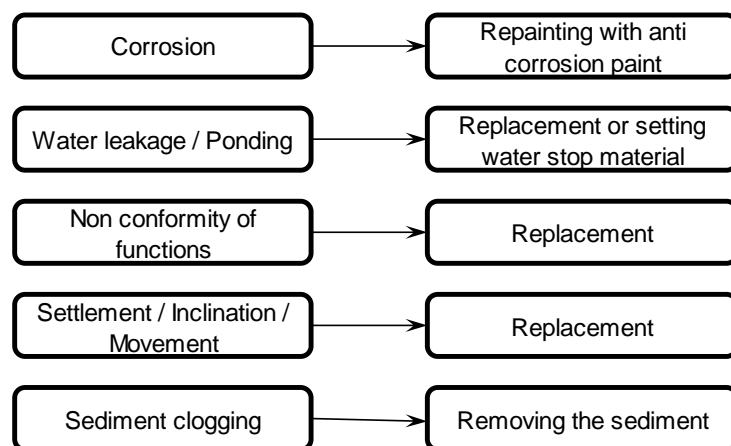


Figure 3.7 Selection of repair bearing

Expansion Joint

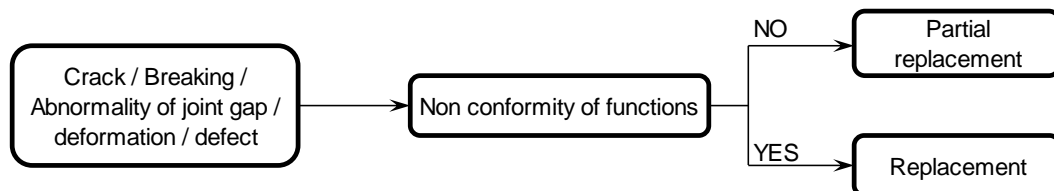
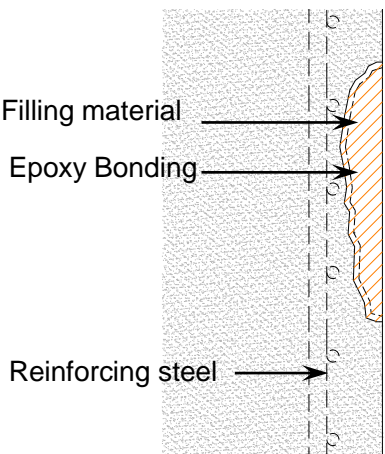
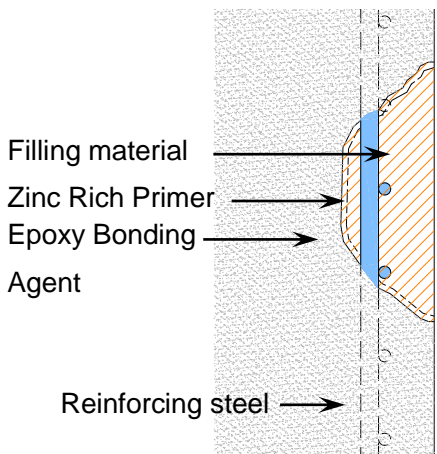


Figure 3.8 Selection of repair method for Expansion joint

3.4. Outline of Repair / Strengthening Method

3.4.1 Repair Methods for Concrete Structures

(1) Plastering method

Minor Repair	Plastering method
Work description	
<p>This method is applied for repairing small areas where concrete is defective, damaged and deteriorated with spalling, scaling and collision. This method is generally used with steel trowel and requires no formwork. Generally, the plastering thickness is limited to maximum of 100mm but it depends on the material to be used. Plastering can apply for both defects with or without exposed reinforcing steel. The material for plastering is cement mortars or polymer cement mortars depending on the type of plastering, location and extent of damage.</p>	
<p style="text-align: center;"><u>Without exposed reinforcing steel</u></p> 	<p style="text-align: center;"><u>With exposed reinforcing steel</u></p> 
Required tools and Equipment (Refer to attachment.4)	
<p><u>Surface preparation</u></p> <ul style="list-style-type: none"> ✓ Power disc grinder ✓ Wire brush / Air gun <p><u>Removing damaged concrete</u></p> <ul style="list-style-type: none"> ✓ Hammer and Chisel / Electric power chisel ✓ Power disc cutter / Handy concrete cutter 	<p><u>Painting</u></p> <ul style="list-style-type: none"> ✓ Brush / Spray gun <p><u>Mixing repair material</u></p> <ul style="list-style-type: none"> ✓ Hand mixer / Grout mixer / Mortar mixer <p><u>Finishing</u></p> <ul style="list-style-type: none"> ✓ Steel trowel <p><u>Others</u></p> <ul style="list-style-type: none"> ✓ Portable generator



Material

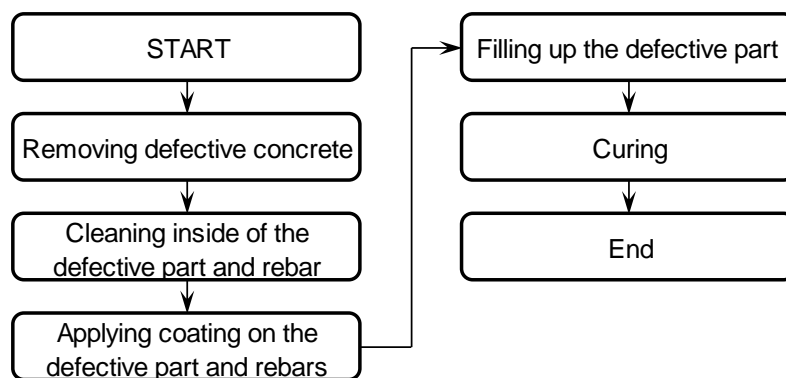
- ✓ Cement mortar
- ✓ Polymer cement mortar

- ✓ Epoxy bonding coat
- ✓ Zinc rich primer


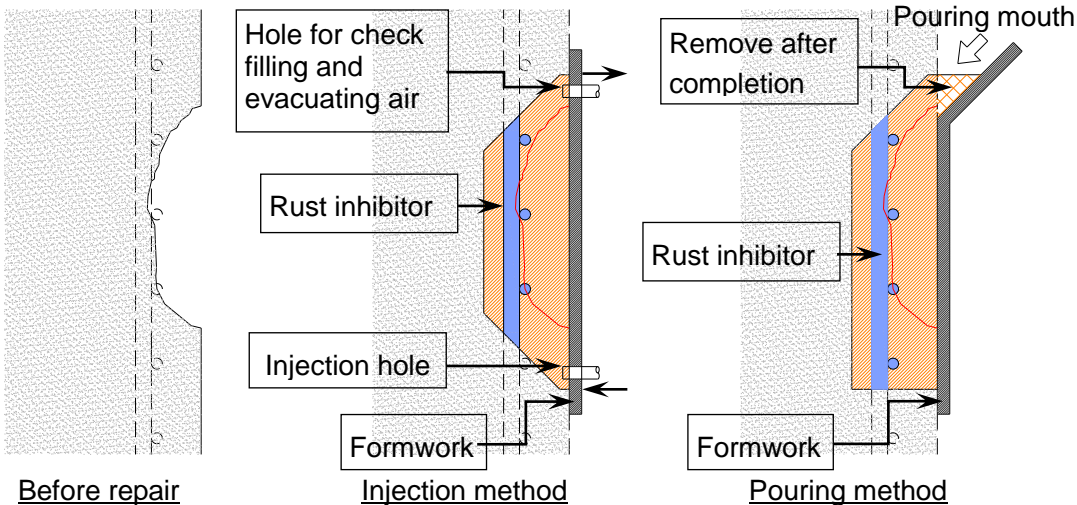
Comparison table for property of material

	Cement mortar	Polymer cement mortar (Polymer cement ratio)
		Low ← → High
Elastic modulus	High ← → Low	
Bending / Tensile strength	Low ← → High	
Adhesive property	Acceptable ← → Good	
Thermal expansion coefficient	Low ← → High	
Heat resistance	High ← → Low	
Electric resistance	Low ← → High	
Deterioration factor resistance	Low ← → High	
Cost	Low ← → High	

Work sequence



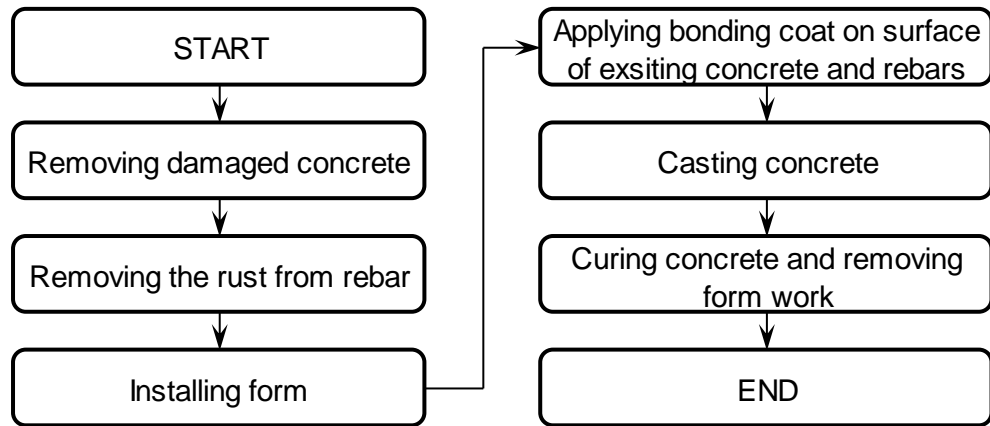
(2) Grouting method – Injecting or Poring

Major Repair	Grouting method – Injecting or Poring
Work description	
<p>This method is generally most suitable for severely defective, damaged and deteriorated concrete, or for largely defective, damaged, deteriorated areas where the reinforcing steel is exposed. This method is generally grouting the area with non-shrinkage mortar or concrete with setting of formwork. If placing concrete by vibration is a problem, free grouting with flowing self-compacting concrete should be adopted to minimize the vibration requirement. Grouting has two categories depending on materials used, i.e. Portland cement and Non-shrink cement. Considering the damaged part, degree of damage, formwork shape and density of reinforcing steel, the application of grouting material such as concrete and grout shall be selected.</p>	
	
	
Required tools and Equipment (Refer to attachment.4)	
<div> <div> <p><u>Surface preparation</u></p> <ul style="list-style-type: none"> ✓ Power disc grinder ✓ Wire brush / Air gun <p><u>Removing damaged concrete</u></p> <ul style="list-style-type: none"> ✓ Electric pick hammer / Electric power chisel ✓ Hammer and chisel ✓ Power disc cutter / Handy concrete cutter ✓ High pressure water blasting <p><u>Painting</u></p> <ul style="list-style-type: none"> ✓ Brush / Spray gun </div> <div> <p><u>Mixing repair material</u></p> <ul style="list-style-type: none"> ✓ Hand mixer / Concrete mixer / Grout mixer / Mortar mixer <p><u>Setting repair material</u></p> <ul style="list-style-type: none"> ✓ Vibrator ✓ Squeeze pump Hopper ✓ Pumping hose <p><u>Finishing</u></p> <ul style="list-style-type: none"> ✓ Steel trowel <p><u>Others</u></p> <ul style="list-style-type: none"> ✓ Portable generator </div> </div>	

Material

- ✓ Polymer cement mortar
- ✓ Non-shrinkage grout
- ✓ Epoxy resin adhesive
- ✓ Anti-corrosion primer to rebar

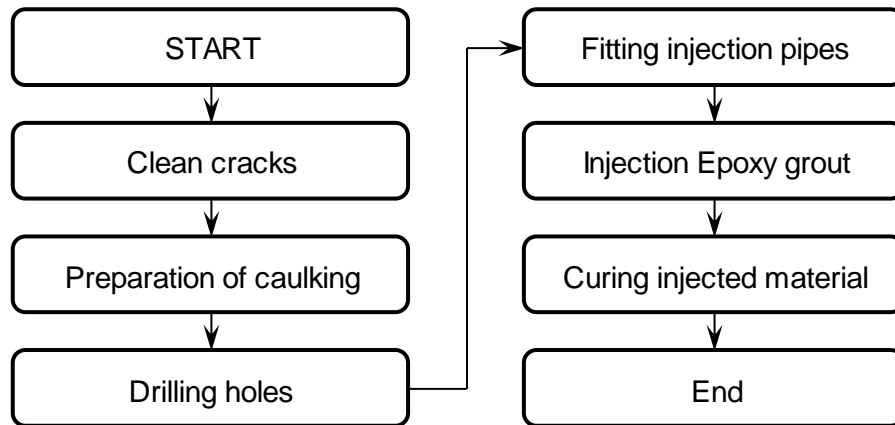
Work sequence




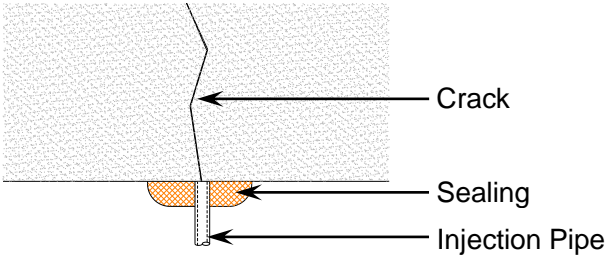
(3) Routing and sealing method

Major Repair	Routing and sealing method
Work description	
<p>This method is generally applied for the crack when width is over 1.0mm. This method can be applied both for active and dormant crack. The sealant is generally installed in a wide recess cut along the crack. The dimensions of recess (width and depth) depend on the total crack movement and the cyclic movement and the capability of the joint sealant used. For selection of filling material, crack movement should be calculated taking into account the applied loads, shrinkage and temperature variations. Crack width should be more than 1.0mm. In this case, the top surface edges should be chipped or sawn to form a V or U - type, in order to provide a caulking for inlet of gravity flow of resin into the crack by injection pump. Cracks wider than 1.0mm generally require epoxy based injection material (mix of epoxy and mineral filler)</p> <div data-bbox="963 353 1458 721"> </div> <div data-bbox="306 837 1289 1146"> </div>	
Required tools and Equipment (Refer to attachment.4)	
<p><u>Surface preparation</u></p> <ul style="list-style-type: none"> ✓ Power disc grinder ✓ Wire brush / Air gun <p><u>Removing damaged concrete</u></p> <ul style="list-style-type: none"> ✓ Electric drill with U shape bit ✓ Handy concrete cutter <p><u>Mixing repair method</u></p> <ul style="list-style-type: none"> ✓ Hand mixer 	<p><u>Setting repair material</u></p> <ul style="list-style-type: none"> ✓ Grout injection pump or gun <p><u>Finishing</u></p> <ul style="list-style-type: none"> ✓ Steel trowel ✓ Power disc grinder <p><u>Others</u></p> <ul style="list-style-type: none"> ✓ Portable generator
Material	
<p><u>Active crack</u></p> <ul style="list-style-type: none"> ✓ Urethane resin ✓ Silicone resin ✓ Sealant resin 	<p><u>Dormant crack</u></p> <ul style="list-style-type: none"> ✓ Flexible epoxy resin <p><u>No movement</u></p> <ul style="list-style-type: none"> ✓ Polymer cement mortar


Work sequence

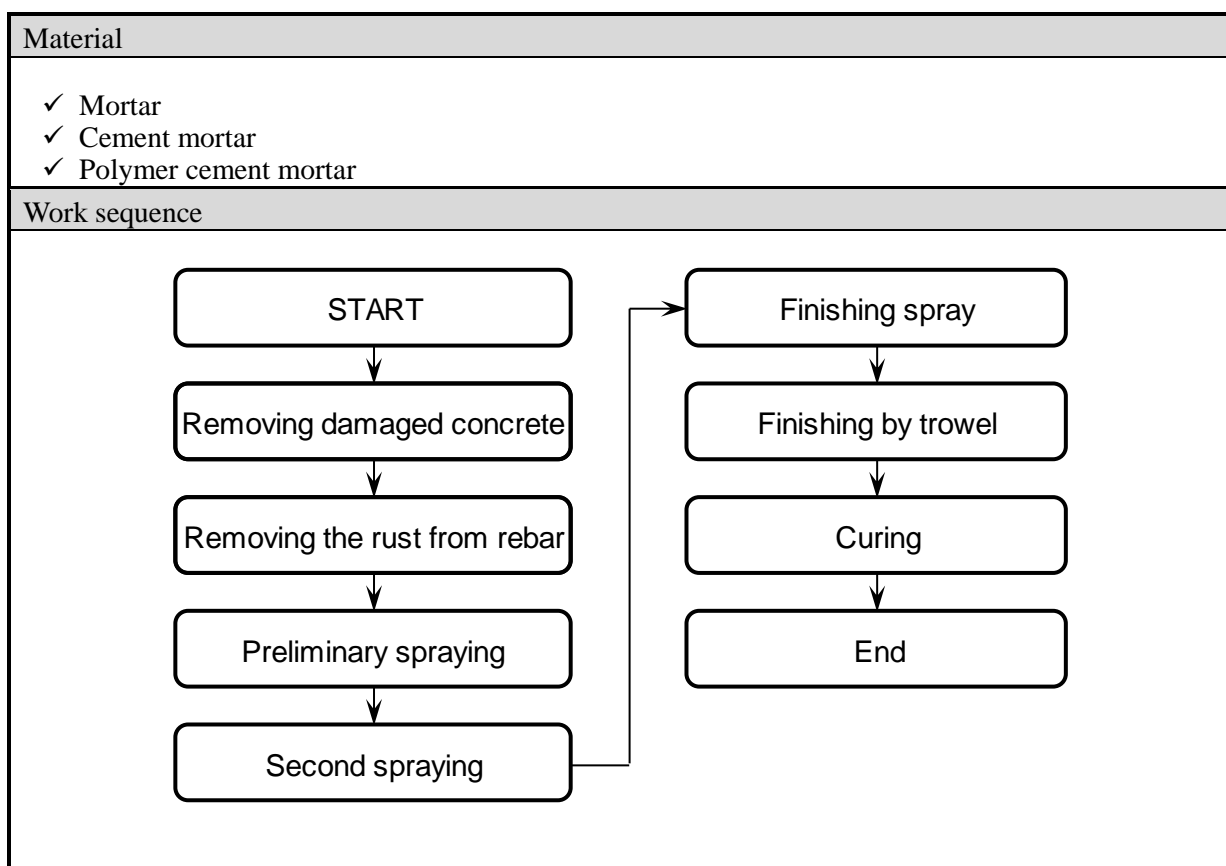


(4) Epoxy injection method

Major Repair	Epoxy injection method
Work description	
<p>This method is generally applied for the crack width which is from 0.2mm to 1.0mm. It can be applied to concrete structures, particularly to deck slab. The work include preparation of concrete surface, insertion of pipe fittings bonded with adhesion, injection of epoxy, curing and conducting performance test. Epoxy injection for concrete cracks requires highly skilled process and its effectiveness depends mostly on the proficiency of a certified technician. The staff assigned should be qualified based on experience and approved by the Engineer in charge.</p>	
<div style="display: flex; justify-content: space-around; align-items: center;">   </div>	
Required tools and Equipment (Refer to attachment.4)	
<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p><u>Surface preparation</u></p> <ul style="list-style-type: none"> ✓ Power disc grinder ✓ Wire brush / Air gun <p><u>Mixing repair method</u></p> <ul style="list-style-type: none"> ✓ Hand mixer </div> <div style="width: 45%;"> <p><u>Setting repair material</u></p> <ul style="list-style-type: none"> ✓ Epoxy injection pump / gun <p><u>Finishing</u></p> <ul style="list-style-type: none"> ✓ Power disc grinder <p><u>Others</u></p> <ul style="list-style-type: none"> ✓ Portable generator </div> </div>	
Material	
<div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p><u>Dormant crack</u></p> <p><u>Organic injection material</u></p> <ul style="list-style-type: none"> ✓ Epoxy resin ✓ Acrylic resin <p><u>Inorganic injection material</u></p> <ul style="list-style-type: none"> ✓ Polymer cement mortar </div> <div style="width: 45%;"> <p><u>Active crack</u></p> <p><u>Organic injection material</u></p> <ul style="list-style-type: none"> ✓ Epoxy resin ✓ Acrylic resin </div> </div>	
Work sequence	
<pre> graph TD START([START]) --> Clean[Clean cracks] Clean --> Adhesion[Adhesion of pipe fitting] Adhesion --> Seal[Seal cracks] Seal --> Fitting[Fitting of injection] Fitting --> Injection[Epoxy injection] Injection --> Curing[Curing injected material] Curing --> Test[Performance test] Test --> END([END]) </pre>	

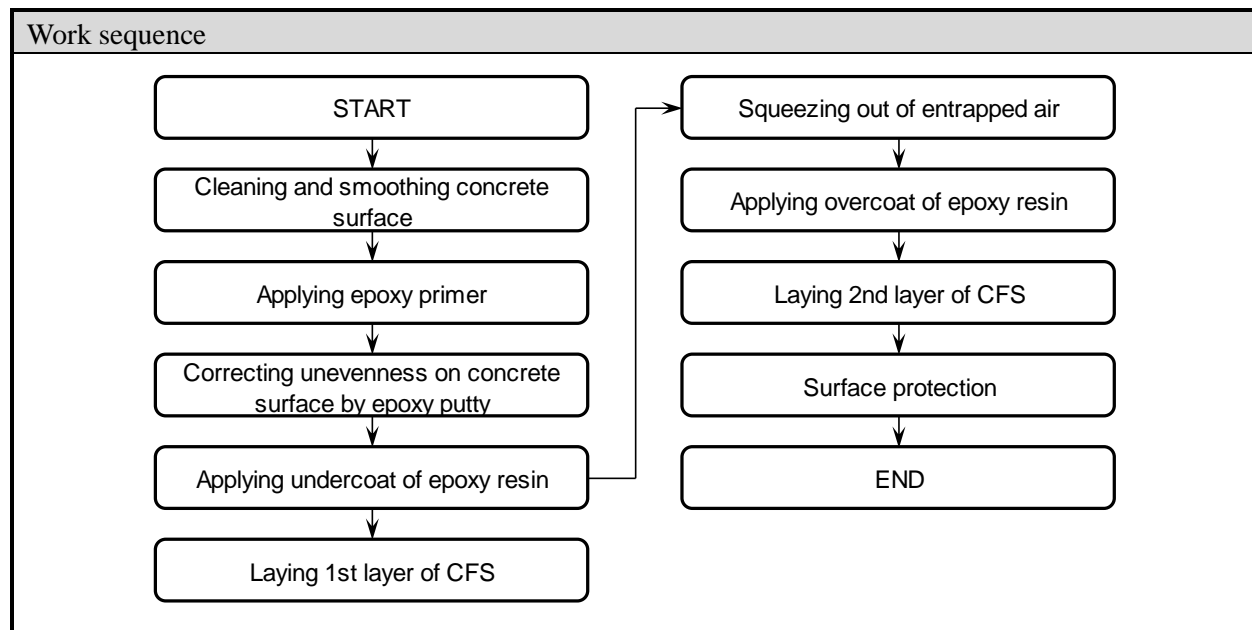
(5) Mortar spraying method

Major Repair	Mortar spraying method																								
Work description																									
<p>This method is generally most suitable for severely damaged concrete, or for large defects, damaged and deteriorated areas exposing the reinforcing steel. Spray gun is used to spray the mortar and concrete by compressed air rendering and profiling of vertical and overhead surfaces.</p> <p>Mortar spraying method is divided in to two namely dry mortar spraying and wet mortar spraying. In the dry mix methods, premix of sand and cement is fed into the hopper of a machine that with the help of compressed air convey the mix through the hose to the nozzle where water is added. For the wet mix method, aggregate, cement, water and admixture are premixed in a concrete plant. The main benefit with the wet mix method versus the dry mortar method is; improved quality, less powdery dust, improved working environment, less rebound, higher capacity and improved safety.</p>																									
																									
<p style="text-align: center;"><u>Comparison table for DRY and WET MORTAR SPRAYING</u></p> <table><tr><th></th><th>DRY MORTAR SPRAYING</th><th>WET MORTAR SPRAYING</th></tr><tr><td>Spraying capacity</td><td>1.0m³ / hour</td><td>0.5m³ / hour</td></tr><tr><td>Thickness of 1 layer</td><td>2~10cm</td><td>2~3cm</td></tr><tr><td>Water content control</td><td>Nozzle</td><td>During mixing</td></tr><tr><td>Interval time of spraying</td><td>Several time~one day</td><td>3hours~one day</td></tr><tr><td>Conveying distance</td><td>~500m</td><td>~50m</td></tr><tr><td>Equipment for spraying</td><td>Large</td><td>Small</td></tr><tr><td>Powdery dust</td><td>Large quantity</td><td>Small quantity</td></tr></table>			DRY MORTAR SPRAYING	WET MORTAR SPRAYING	Spraying capacity	1.0m ³ / hour	0.5m ³ / hour	Thickness of 1 layer	2~10cm	2~3cm	Water content control	Nozzle	During mixing	Interval time of spraying	Several time~one day	3hours~one day	Conveying distance	~500m	~50m	Equipment for spraying	Large	Small	Powdery dust	Large quantity	Small quantity
	DRY MORTAR SPRAYING	WET MORTAR SPRAYING																							
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Conveying distance	~500m	~50m																							
Equipment for spraying	Large	Small																							
Powdery dust	Large quantity	Small quantity																							
Required tools and Equipment (Refer to attachment.4)																									
<p><u>Surface preparation</u></p> <ul style="list-style-type: none">✓ Power disc grinder✓ Wire brush / Air gun <p><u>Removing damaged concrete</u></p> <ul style="list-style-type: none">✓ High pressure water blasting✓ Electric pick hammer / Electric power chisel / Hammer and Chisel✓ Power disc cutter / Handy concrete cutter <p><u>Painting</u></p> <ul style="list-style-type: none">✓ Brush / Spray gun <p><u>Mixing repair method</u></p> <ul style="list-style-type: none">✓ Mortar mixer <p><u>Finishing</u></p> <ul style="list-style-type: none">✓ Steel trowel	<p><u>Setting repair material (Dry mortar)</u></p> <ul style="list-style-type: none">✓ Dry spray nozzle✓ Air compressor✓ Dry mortar spraying equipment✓ Hopper✓ Water tank✓ High washer pump <p><u>Setting repair material (Wet mortar)</u></p> <ul style="list-style-type: none">✓ Wet spray nozzle✓ Air compressor✓ Hopper✓ Squeeze pump✓ Pumping hose <p><u>Others</u></p> <ul style="list-style-type: none">✓ Portable generator																								




(6) Continuous fiber reinforced sheet bonding


Major Repair		Continuous fiber reinforced sheet bonding (CFRS)
Work description		
<p>This method is used for reinforced concrete repairs and strengthening. System consist of a combination of continuous fiber reinforced material and adhesive resin such as epoxies and other materials. The composite product is intended to enhance the capacity of the concrete deck slab and extend its service life. The function of resin is to serve as an adhesive bond onto the concrete surface and facilitate the transfer of stress to and from the continuous fiber reinforced sheet.</p> <p>This work consists of furnishing and installing two type of continuous fiber reinforced sheets for concrete strengthening system in accordance with the plans and specifications. The system shall be designed to strengthen and stiffen concrete bridge deck slab and tested by the Engineer to verify performance. The related strengthening system for the concrete deck slab shall generally consist of continuous fiber reinforced sheet bonding to the concrete surface with epoxy adhesive.</p> <p>The continuous arrangement is commonly used during the early stage of CFRS bonding application at the bottom of the deck slab. However, in most of the cases it is observed that the entrapped air which could be easily released was found in the installed CFS. These air voids reduce bond strength between CFRS and concrete surface and must be squeezed out by roller. On the other hand, in the grid arrangement, CFRS does not totally cover the required surface due to which, the CFRS is installed in strap-type method in both directions. According to experimental results, effectiveness of the second system is almost the same as that of continuous arrangement. Moreover, entrapped air in the second system can be squeezed out easily using a roller. Thus, the grid arrangement is recommended considering its ease of application, least cost and acceptable effectiveness. The CFRS should be applied as two layers in both the longitudinal and transverse directions.</p>		
 <p>Continuous arrangement</p>		 <p>Grid arrangement</p>
Required tools and Equipment (Refer to attachment.4)		
<u>Surface preparation</u> ✓ Power disc grinder ✓ Wire brush / Air gun <u>Painting</u> ✓ Brush / Brush roller ✓ Steel trowel		<u>Mixing repair method</u> ✓ Hand mixer <u>Others</u> ✓ Portable generator
Material		
✓ Carbon fiber sheet ✓ Epoxy primer		✓ Epoxy putty ✓ Epoxy resin adhesive



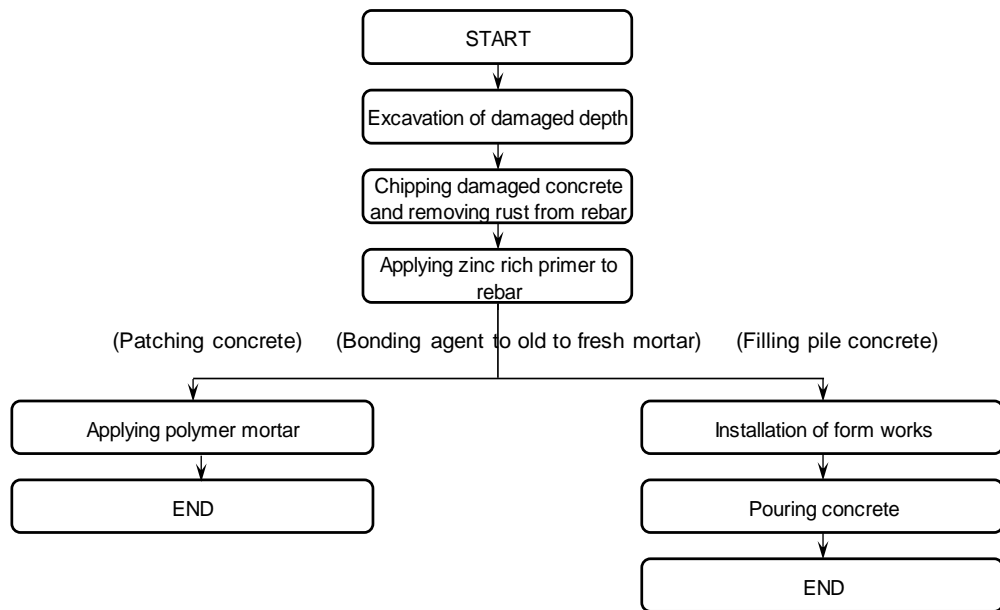
(7) Partial replacement of deck slab

Major Repair	Partial replacement of deck slab
Work description	
<p>This method is used for replacing portion of the concrete that are severely defective, damaged and deteriorated. If the part is not removed, the defect, deterioration will be further aggravated which could impair the strength, stability and serviceability of the structure. The presence of such defect, damage and deterioration lead to corrosion of the reinforcing rebar, fracturing, spalling, delamination, honeycombing of concrete or water leakages. Generally, recasting concrete involve removal of the defective, damaged and deteriorated concrete area, cleaning up of substrate and reinforcement, setting up formwork and placement of new concrete.</p>	
	
Required tools and Equipment (Refer to attachment.4)	
<p><u>Surface preparation</u></p> <ul style="list-style-type: none"> ✓ Power disc grinder ✓ Wire brush / Air gun <p><u>Removing damaged concrete</u></p> <ul style="list-style-type: none"> ✓ Concrete cutter / Handy concrete cutter ✓ Hammer and Chisel / Electric power chisel , Electric pick hammer ✓ High pressure water blasting <p><u>Painting</u></p> <ul style="list-style-type: none"> ✓ Brush / Spray gun 	<p><u>Mixing repair method</u></p> <ul style="list-style-type: none"> ✓ Concrete mixer <p><u>Setting repair material</u></p> <ul style="list-style-type: none"> ✓ Vibrator ✓ Squeeze pump ✓ Hopper ✓ Pumping hose <p><u>Finishing</u></p> <ul style="list-style-type: none"> ✓ Steel trowel <p><u>Others</u></p> <ul style="list-style-type: none"> ✓ Portable generator
Material	
<ul style="list-style-type: none"> ✓ Portland cement ✓ Silica fume ✓ Epoxy resin (bonding coat to concrete) ✓ Zinc rich primer (Bonding coat to rebar) 	
Work sequence	
<pre> graph TD START([START]) --> Protecting[Protecting existing structure] Protecting --> Removing[Removing damaged concrete] Removing --> Replacing[Replacing rusted rebars] Replacing --> Installing[Installing form] Installing --> Bonding[Applying bonding coat on surface of existing concrete and rebars] Bonding --> Casting[Casting concrete] Casting --> Curing[Curing concrete and removing form] Curing --> END([END]) </pre>	

(8) Plastering / Grouting Pile Concrete

Minor Repair	Plastering / Grouting Pile Concrete		
<p>Work description</p> <p>Due to scouring some of bored pile head areas below a pile cap may appear above ground surface with spalling cover concrete / missing concrete section and exposing reinforcing steel.</p> <p>Plastering repair of bored concrete pile is carried out to restore small areas where sound concrete is defective, damaged and deteriorated by spalling, scaling and impact. This method is generally applied using trowel and required minimum or no formworks. On the other hand, the concrete is filled inside the bored pile where inadequate concreting had occurred.</p> <p>Plastering of pile concrete is applicable when the concrete is spalled with the exposure of reinforcing steel and polymer cement mortar is used for in such repairs. The pile which has a missing section of concrete with exposed reinforcing steel should be filled with concrete, in such cases, Portland cement should be used in concrete.</p>			
			
<p>Required tools and Equipment (Refer to attachment.4)</p> <table> <tr> <td> <p><u>Surface preparation</u></p> <ul style="list-style-type: none"> ✓ Power disc grinder ✓ Wire brush / Air gun <p><u>Removing damaged concrete</u></p> <ul style="list-style-type: none"> ✓ Hammer and Chisel / Electric power chisel ✓ Power disc cutter / Handy concrete cutter </td><td> <p><u>Painting</u></p> <ul style="list-style-type: none"> ✓ Brush / Spray gun <p><u>Mixing repair material</u></p> <ul style="list-style-type: none"> ✓ Hand mixer / Grout mixer / Mortar mixer <p><u>Finishing</u></p> <ul style="list-style-type: none"> ✓ Steel trowel <p><u>Others</u></p> <ul style="list-style-type: none"> ✓ Portable generator </td></tr> </table>		<p><u>Surface preparation</u></p> <ul style="list-style-type: none"> ✓ Power disc grinder ✓ Wire brush / Air gun <p><u>Removing damaged concrete</u></p> <ul style="list-style-type: none"> ✓ Hammer and Chisel / Electric power chisel ✓ Power disc cutter / Handy concrete cutter 	<p><u>Painting</u></p> <ul style="list-style-type: none"> ✓ Brush / Spray gun <p><u>Mixing repair material</u></p> <ul style="list-style-type: none"> ✓ Hand mixer / Grout mixer / Mortar mixer <p><u>Finishing</u></p> <ul style="list-style-type: none"> ✓ Steel trowel <p><u>Others</u></p> <ul style="list-style-type: none"> ✓ Portable generator
<p><u>Surface preparation</u></p> <ul style="list-style-type: none"> ✓ Power disc grinder ✓ Wire brush / Air gun <p><u>Removing damaged concrete</u></p> <ul style="list-style-type: none"> ✓ Hammer and Chisel / Electric power chisel ✓ Power disc cutter / Handy concrete cutter 	<p><u>Painting</u></p> <ul style="list-style-type: none"> ✓ Brush / Spray gun <p><u>Mixing repair material</u></p> <ul style="list-style-type: none"> ✓ Hand mixer / Grout mixer / Mortar mixer <p><u>Finishing</u></p> <ul style="list-style-type: none"> ✓ Steel trowel <p><u>Others</u></p> <ul style="list-style-type: none"> ✓ Portable generator 		
<p>Material</p> <table> <tr> <td> <p><u>Plastering</u></p> <ul style="list-style-type: none"> ✓ Cement mortar ✓ Polymer cement mortar ✓ Epoxy bonding coat ✓ Zinc rich primer </td><td> <p><u>Grouting</u></p> <ul style="list-style-type: none"> ✓ Polymer cement mortar ✓ Non-shrinkage grout ✓ Epoxy bonding coat ✓ Zinc rich primer </td></tr> </table>		<p><u>Plastering</u></p> <ul style="list-style-type: none"> ✓ Cement mortar ✓ Polymer cement mortar ✓ Epoxy bonding coat ✓ Zinc rich primer 	<p><u>Grouting</u></p> <ul style="list-style-type: none"> ✓ Polymer cement mortar ✓ Non-shrinkage grout ✓ Epoxy bonding coat ✓ Zinc rich primer
<p><u>Plastering</u></p> <ul style="list-style-type: none"> ✓ Cement mortar ✓ Polymer cement mortar ✓ Epoxy bonding coat ✓ Zinc rich primer 	<p><u>Grouting</u></p> <ul style="list-style-type: none"> ✓ Polymer cement mortar ✓ Non-shrinkage grout ✓ Epoxy bonding coat ✓ Zinc rich primer 		

Work sequence


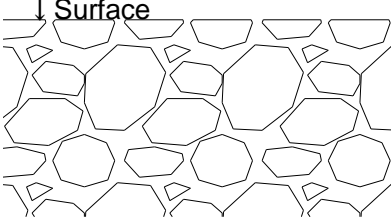
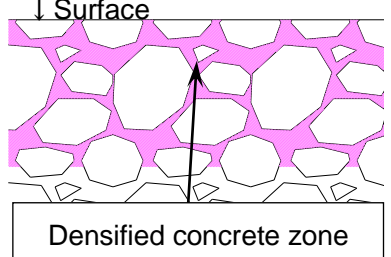


(9) Sacrifice Anode material


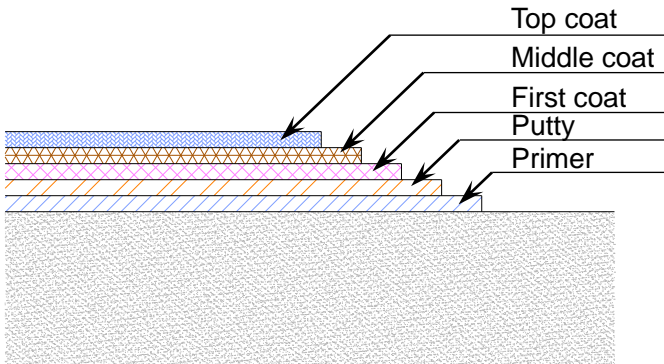
Supplement method	Sacrifice Anode material
<p>Work description</p> <p>This method is used as supplement by attaching the sacrifice anode material to the reinforcement steel embedded in concrete to prevent corrosion that is occurring normally, it is effective for the corrosion caused by salt or due to carbonation.</p> <p>Sacrifice anode material is used to galvanically protect reinforcement steel in chloride contaminated concrete, and thereby avoid future problems associated with the formation of incipient anodes.</p> <p>Sacrifice anode material is fixed to reinforcement steel by wire ties which can attach in horizontal, vertical and overhead locations whilst ensuring electrochemical continuity.</p>	
<p>Required tools and Equipment (Refer to attachment.4)</p> <div> <div> <p><u>Surface preparation</u></p> <ul style="list-style-type: none"> ✓ Power disc grinder ✓ Wire brush / Air gun <p><u>Removing damaged concrete</u></p> <ul style="list-style-type: none"> ✓ Hammer and Chisel / Electric power chisel ✓ Power disc cutter / Handy concrete cutter </div> <div> <p><u>Painting</u></p> <ul style="list-style-type: none"> ✓ Brush <p><u>Mixing repair material</u></p> <ul style="list-style-type: none"> ✓ Hand mixer / Grout mixer / Mortar mixer <p><u>Finishing</u></p> <ul style="list-style-type: none"> ✓ Steel trowel <p><u>Others</u></p> <ul style="list-style-type: none"> ✓ Portable generator </div> </div>	
<p>Material</p> <ul style="list-style-type: none"> ✓ Sacrifice anode material (Zinc) 	
<p>Work sequence</p> <pre> graph TD START([START]) --> A[Removing defective concrete] A --> B[Removing the rust from rebar] B --> C[Attaching sacrifice anode material to the reinforcing steel] C --> D[Painting primer] D --> E[Repairing the concrete section loss by plastering or spraying] E --> F[Curing] F --> End([End]) </pre>	





(10) Substrate impregnation

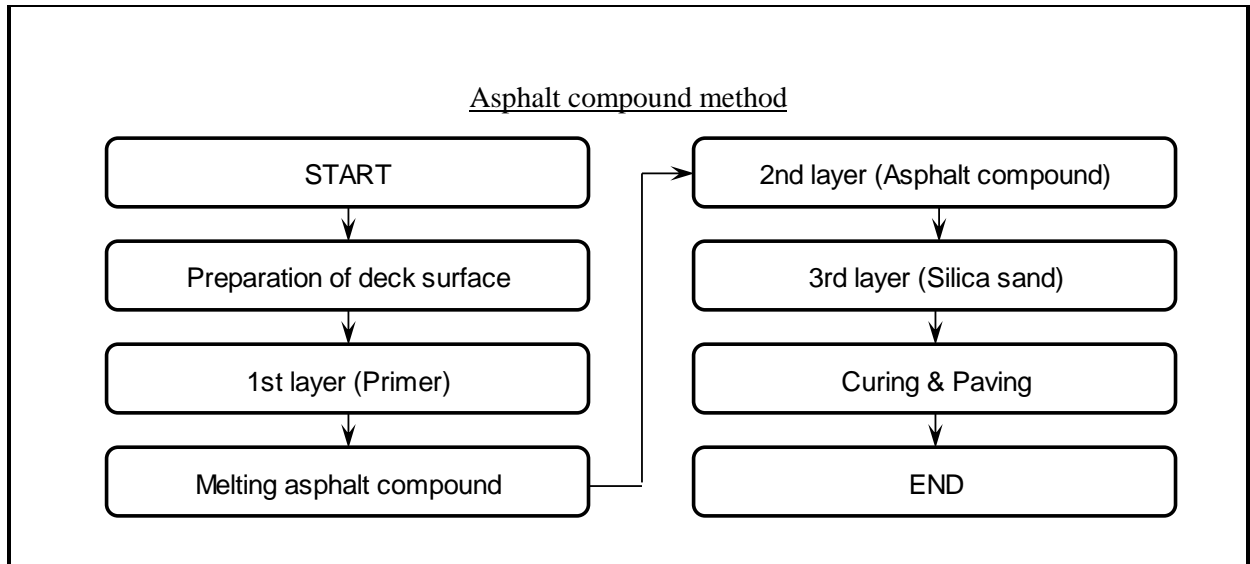
Supplement method	Substrate impregnation
<p>Work description</p> <p>This method is used as supplement when painting substrate impregnation on concrete surface. On surface application, it penetrates the concrete and improves its properties in specific ways, such as densifying, strengthening, enhancing alkalinity, or enhancing water repelling properties.</p> <p>All types of surface penetrant have a number of advantageous characteristics, (1) they are colorless and transparent, ensuring no degradation of the external appearance of the concrete surface; (2) they can be applied easily and quickly, with little effort compared to other techniques such as coating methods or lining methods; (3) they are environmentally friendly as little industrial waste is generated and they do not require organic solvents or other harmful chemicals.</p> <div style="display: flex; align-items: center;">  <div style="margin-left: 20px;"> <p>Before using</p>  <p style="text-align: center;">↓ Surface</p> </div> <div style="margin-left: 20px;"> <p>After using</p>  <p style="text-align: center;">↓ Surface</p> <p style="text-align: center;">Densified concrete zone</p> </div> </div>	
<p>Required tools and Equipment (Refer to attachment.4)</p> <div style="display: flex; justify-content: space-between;"> <div style="width: 45%;"> <p><u>Surface preparation</u></p> <ul style="list-style-type: none"> ✓ High pressure water blasting </div> <div style="width: 45%;"> <p><u>Painting</u></p> <ul style="list-style-type: none"> ✓ Brush roller ✓ Spray gun </div> </div>	
<p>Material</p> <ul style="list-style-type: none"> ✓ Calcium nitrite 	
<p>Work sequence</p> <pre> graph TD START([START]) --> SurfacePrep[Surface preparation] SurfacePrep --> Wetting[Wetting or drying surface] Wetting --> Painting[Painting substrate impregnation] Painting --> End([End]) </pre>	

(11) Surface coating




Supplement method	Surface coating
<p>Work description</p> <p>This method is used as supplemental to prevent the ingress of factors that can cause deterioration of the concrete or prevent spalling of concrete cover by forming a protective film on the concrete surface. Surface coating can be broadly classified into organic material and inorganic material.</p> <div style="display: flex; align-items: center;">   </div>	
<p>Required tools and Equipment (Refer to attachment.4)</p> <div style="display: flex; justify-content: space-between;"> <div> <p><u>Surface preparation</u></p> <ul style="list-style-type: none"> ✓ Power disc grinder ✓ Steel trowel <p><u>Painting</u></p> <ul style="list-style-type: none"> ✓ Brush roller, Brush </div> <div> <p><u>Mixing repair material</u></p> <ul style="list-style-type: none"> ✓ Hand mixer </div> </div>	
<p>Material</p> <div style="display: flex; justify-content: space-between;"> <div> <p><u>Organic coating material</u></p> <ul style="list-style-type: none"> ✓ Epoxy resin ✓ Vinyl ester resin ✓ Acrylic rubber <p><u>Inorganic coating material</u></p> <ul style="list-style-type: none"> ✓ Polymer cement mortar </div> <div> <p><u>Others</u></p> <ul style="list-style-type: none"> ✓ Epoxy putty ✓ Primer </div> </div>	
<p>Work sequence</p> <pre> graph TD START([START]) --> SurfacePrep[Surface preparation] SurfacePrep --> Primer[Painting the primer] Primer --> SurfaceLeveling[Surface leveling] SurfaceLeveling --> Intermediate[Painting intermediate coating] Intermediate --> Finish[Painting finish coating] Finish --> Curing[Curing] Curing --> END([END]) </pre>	

(12) Water proofing

Supplement method	Water proofing
<p>Work description</p> <p>Concrete is usually alkaline and therefore protects the reinforcing steel. However, the effect of its contact with water and corrosive materials reduce the alkaline environment and allows an electrolytic process to commence, thus corroding the reinforcement steel.</p> <p>The primary protection against this destructive damage is through installation of waterproofing membrane or asphalt compound on the deck slab.</p>	
<div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">  <p><u>Rubberized membrane</u></p> </div> <div style="text-align: center;">  <p><u>Asphalt compound</u></p> </div> </div>	
<p>Required tools and Equipment (Refer to attachment.4)</p>	
<p><u>Rubberized membrane</u></p> <ul style="list-style-type: none"> ✓ Paint roller 	<p><u>Asphalt compound</u></p> <ul style="list-style-type: none"> ✓ Kettle with heater ✓ Roller brush ✓ Rubber brush
<p>Material</p>	
<p><u>Rubberized membrane</u></p> <ul style="list-style-type: none"> ✓ Primer ✓ Rubberized membrane ✓ Tack coat 	<p><u>Asphalt compound</u></p> <ul style="list-style-type: none"> ✓ Primer ✓ Asphalt compound membrane ✓ Silica sand
<p>Work sequence</p>	
<p style="text-align: center;"><u>Rubberized membrane method</u></p> <pre> graph TD START([START]) --> Prep[Preparation of Deck surface] Prep --> 1st[1st layer (Primer)] 1st --> 2nd[2nd layer (Base coat)] 2nd --> 3rd[3rd layer (Inter coat)] 3rd --> 4th[4th layer (Top coat)] 4th --> 5th[5th layer (Tack coat)] 5th --> END([END]) </pre>	



(13) Corrosion inhibitor

Supplement method	Corrosion inhibitor
<p>Work description</p> <p>This supplement method is effective to prevent the formation of rust on reinforcing steel.</p> <p>Before applying corrosion inhibitor on reinforcing bar, generated rust on reinforcing steel and defective, damaged and deteriorated concrete shall be removed.</p> <p>Application should be in a dry and clean environment as data sheet required.</p> <p>Thickness of the coating and waiting time between applications shall be in accordance with data sheet.</p>	
 <p><u>Zinc rich primer system</u></p>	 <p><u>Polymer cement system</u></p>
 <p><u>Epoxy resin system</u></p>	
<p>Required tools and Equipment (Refer to attachment.4)</p>	
<p>✓ Brush / Spray gun</p>	<p>✓ Wire brush</p>
<p>Material</p>	
<p>✓ Zinc rich primer system</p> <p>✓ Polymer cement system</p>	<p>✓ Epoxy resin system</p>

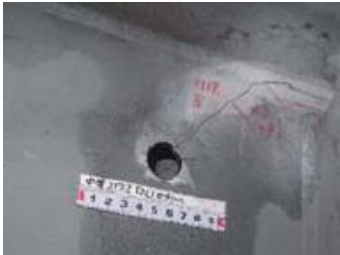
3.4.2 Repair methods for steel structure

(1) Supplementing steel plate bonding

Major Repair	Supplementing steel plate bonding
<p>Work description</p> <p>Defects of a steel structure can be categorized as (a) rusting / corrosion (b) crack / breakage (c) deformation (d) losing / missing bolts etc.</p> <p>The causes of above defects of the steel structure will be (a) lack of maintenance by painting (b) over stress due to the heavy traffic (c) vibration caused by traffic (d) fatigue (e) lack of required considerations for a detailed structural design etc.</p> <p>Supplemental steel plate is provided to restore lost strength of the steel member by adding a new steel plate to a damaged area or by replacing damaged member with a new steel plate. Supplemental steel plate without replacement of a member will be applicable to crack / breakage of the member. Also supplemental steel plate with partial replacement of a member will be applicable when deterioration of member takes place.</p>	
<p>Required tools and Equipment (Refer to attachment.4)</p>	
<p><u>Surface preparation</u></p> <ul style="list-style-type: none"> ✓ Disc sander ✓ Wire brush ✓ Power disc grinder <p><u>Cutting and drilling</u></p> <ul style="list-style-type: none"> ✓ Gas cutter ✓ Electric drill <p><u>Welding</u></p> <ul style="list-style-type: none"> ✓ Welding plant 	<p><u>Bolting</u></p> <ul style="list-style-type: none"> ✓ Fastening wrench ✓ Electric wrench <p><u>Painting</u></p> <ul style="list-style-type: none"> ✓ Paint brush <p><u>Others</u></p> <ul style="list-style-type: none"> ✓ Portable generator
<p>Work sequence</p> <pre> graph TD START([START]) --> A[Removing rust and surface treatment] A --> B[Positioning of cutting area] B --> C[Driling the bolt hole to the stee member] C --> D[Gas cutting] D --> E[Surface treatment of cutting section] E --> F[Driling the bolthole to the steel plate] F --> G[Setting additional steel plate inside of cutting area] G --> H[Setting additional steel plate on cutting area by HSFG] H --> I[Painting] I --> END([END]) </pre>	



(2) Stop hole

Supplement method	Stop hole
Work description	
<p>This method is one of useful countermeasures against fatigue cracks originated in steel members.</p> <p>This method is drilling a hole at the edge of fatigue crack for reduction of stress concentration. It should be combined with another method like supplementing steel plate bonding method.</p>	
Required tools and Equipment (Refer to attachment.4)	
✓ Electric drill	
Work sequence	
 <pre> graph TD START([START]) --> Investigate[Investigate the edge of crack] Investigate --> Drilling[Drilling hole at edge of crack] Drilling --> Removing[Removing the burrs and surface treatment around hole] Removing --> END([END]) </pre>	

3.5. Recording of Bridge Repair Results

After completion of the Repair / Strengthening work, the result shall be recorded in both Form General Information of Maintenance” and “Work Description of a Bridge”.

(1) General Information of Maintenance

General Information of Maintenance shall be recorded by EE Office at each province.

Target Bridge shall be selected from Inventory.

Table 5.1 General Information of Maintenance

Maintenance Report				
General Information of Maintenance				
Work No.	:	①	Work Name	: ⑤
Work Amount	:	Rs ②	Contractor	: ⑥
Year	:	③	Work Period	: ⑦ ~
Management Office	:	④	Work By	: ⑧ Contract Force Account
Target Bridge				
No.	Route No.	Name of Road	Bridge No.	Name of Bridge
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
Remarks :				

- 1). Work No
The ordering number shall be recorded.
- 2). Work Amount
Total cost of Repair work shall be recorded.
- 3). Year
The ordering year shall be recorded.
- 4). Management Office
Representative office which is conducting the Repair work shall be recorded.
- 5). Work name
The project name shall be recorded.
- 6). Contractor
The contractor's name shall be recorded, in case the repair work was performed by a contractor.
- 7). Work period
The total duration of repair work at each ordering unit shall be recorded.
- 8). Work by
Contract or Force account shall be selected
- 9). Remark
The important information exceptions as necessary shall be recorded

(2) Work Description of a Bridge

Work description of a bridge shall be recorded for each bridge.

In this sheet “Work on”, “Category of Work”, “Work Item”, “Target HI”, “Quantity” and “Unit” shall be recorded. Other items are automatically entered from inventory.

Table 5.2. Work Description of a Bridge

Work Description of A Bridge						
Route No.	: A002			Name of Road	: Colombo-Galle-Hambantota-Wellawaya	
Bridge No.	: 199 / 4 in Km			Name of Bridge	:	
Separation	: Not Separated			Widened	: Not Widened	
Province	: Southern			District	: Hambantota	
EE Division	: Tangalle					
Length of Bridge(m)	: 7.600			Total Number of Span	: 1	
Span Arrangement	:					
Width(m)	: Overall: 10.80			Effective: 10.20	Center Median:	
Width of Cross Sec.(m)	: Left Sidewalk: 0.95			Carriageway: 8.30	Righ Sidewalk: 0.95	
Skew Angle(degree)	: 0					
No.	Work On	Category of Work	Work Item	Target HI	Quantity	Unit
1	①	①	①	②	①	①
2						
3						
4						
5						
6						
7						
8						
9						
10						
Remarks	: ③					

(1) Classification of “Work On”, “Category of work”, “Work item” and “Unit”

Classification of Work On, Category of work, Work item and Unit refer Table 5.3.

Table 5.3 Classification of Work On, Category of Work, Work Item and Unit

Work On		Category of Work		Work Item		Unit
1	Bridge Surface	1	Maintenance	—	—	Span : Number of repaired spans
		2	Repair	1	Replacement of pavement	
				2	Replacement of Expansion Joint	
				3	Replacement of Accessories (Drainage / Service duct / Railing / Parapet)	
				4	Repair work for approach road	
		3	Others※	—	—	
2	Superstructure	1	Maintenance	—	—	Span : Number of Repaired spans
		2	Repair	1	Concrete Main / Cross Beam	
				2	Steel Main / Cross Beam	
				3	Concrete deck slab	
				4	Steel deck slab	
		3	Others※	—	—	
3	Bridge Bearing	1	Maintenance	—	—	Span : Number of Repaired spans
		2	Repair	—	Replacement of Bearing	
		3	Others※	—	—	
4	Substructure	1	Maintenance	—	—	Nos : Number of Repaired piers or abutments
		2	Repair	1	Repair work for Substructure	
				2	Countermeasure against scour	
		3	Others※	—	—	
5	Others	1	Maintenance	—	—	Record the unit according to each category of work.
		2	Repair	—	—	
		3	Others※	—	—	
Note						
※Detail information shall be recorded in Remarks.						

(2) Target HI

The management level (target health index) for the member at each bridge unit shall be recorded by BM&AU members.

(3) Remarks

The important information such as detail repair or strengthening method, position, material or coating system applied shall be recorded.

Attachment 1 - Specification for Plastering Method

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1. Work flow and requirement

If repair work is to be conducted by adopting plastering method (procedure), prior to commencement of the repairs the contractor should submit a proposal explaining the procedure to the Engineer in charge for his perusal and approval before commencement of Repairs.

1.) Preparatory Inspection

Identify the location of delaminating, spalling surface, deteriorated concrete by hammer tapping or other suitable method.



2.) Marking Cut Lines

Mark the cutting lines by tape or chalk.

The cutting line should be approximately 30mm from the edge of the deteriorated surface.

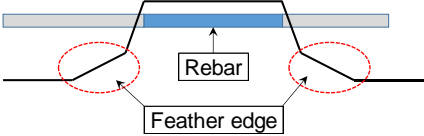
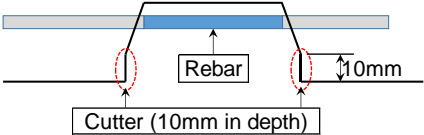



3.) Saw Cut

In order to prevent the formation of the featheredge, saw cut or disk cutter should be used. Depth of the saw cut shall be around 10mm. Feather edge lead to separation of repair material. Care should be taken to prevent damages to the existing steel reinforcements.



Table 1.1 Example of Repaired Section

Comparison of Sections Prepared for Repairs	Good Example of Section Prepared for Repairs
<p><u>Bad preparation of repair section</u></p>  <p><u>Good Preparation of repair section</u></p> 	

4.) Removal of Defective Concrete

Remove all defective, unsound and contaminated concrete and prepare the edge of the patching area as shown in the attached photo. If local corrosion in steel reinforcements with section losses is found requiring additional bars, remove only the damaged concrete including the sections of steel bars that is required to bond the new reinforcements with new steel bars.

Concrete within the marked areas shall be removed using light mechanical breakers or hammers and chisels. All the exposed steel reinforcements should be removed and sound of concrete substrate should be used to determine the nature of the concrete to the satisfaction of the Engineer in charge, before breaking the concrete beneath the steel reinforcements. To avoid generation of micro cracks, it is recommended to use high pressure water blasting method.



Table 1.2 Water Jets and Grade of Water Pressures in Use

Grade of Water Pressure	Description
Low Pressure (Up to 18N/mm ² (MPa) / 180bar / ~2,600PSI)	Used for cleaning concrete and steel substrate
High Pressure (From 18 to 60 N/mm ² (MPa) / 600bar / ~ 8,700PSI)	Used for cleaning steel substrate and for removal of concrete
Very High Pressure (From 60 to 110N/mm ² (MPa) / 1,100bar / ~ 16,000PSI)	Used for concrete removal when low water volume is available

※ Extracted from EN1504-1



5.) Inspection after Chipping

Inspect overhang, featheredge, air ventilation, loose materials, rust on steel reinforcements and surrounding space identified for repair mortal etc.

6.) Cleaning of Concrete and Steel Reinforcements

Remove loose particles and dust using light pressure water or vacuum cleaner. Concrete surface to be bonded must be free from dirt, oil, grease, asphalt etc. Corrosion must be removed before placing the new concrete. If deterioration is due to chloride contamination or if the steel reinforcements is covered with loose corrosion elements having pits, use high pressure water blasting until all the rust is removed. The concrete surfaces selected for repair shall be prepared by mechanical scrubbing to remove loose materials, surface laitance, organic contaminants and moss, and then coated by bonding primer. Utmost care shall be taken to ensure that vibration generated during the process does not cause delamination of adjacent render or concrete.

Table 1.3 Reference Photos of Surface Treatment of Steel Reinforcements

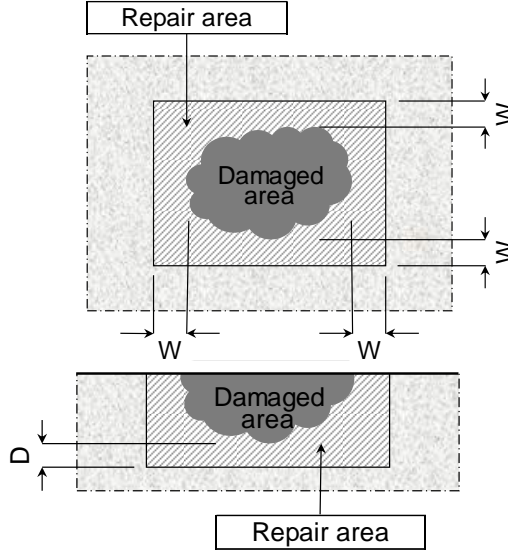
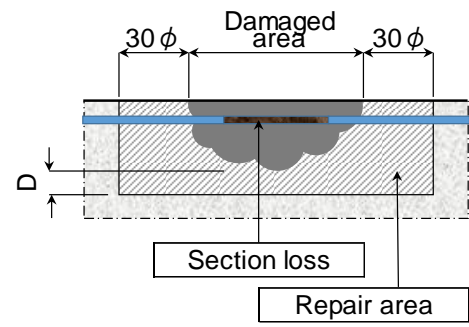
Removing Rust from Reinforcing steel by hand tool	Removing rust from reinforcing steel by power tool
	

7.) Additional Concrete Breakout (Removal)

Where the breakout (removed) section indicates that the exposed reinforced steel is further corroded or the surrounding concrete is not sound, an enlarged area should be taken for demolition to the satisfaction of the Engineer in charge.

The depth of removal of concrete in clearly defined areas can be increased based on the written instructions from Engineer in order to remove all defected, damaged and deteriorated concrete. The additional concrete excavation shall not extend more than 20mm from the bottom layer of main steel reinforcements. During removal utmost care should be undertaken to minimize damage to existing steel. Used for reinforcements.

Table 1.4 Example of additional concrete breakout (Removal)

Case1. Reinforcing Steel Unaffected	Case.2 Reinforcing Steel Affected
 <p>Note : W and D shall be at least 20mm</p>	 <p>Note : W and D shall be at least 20mm</p>

8.) Additional or Replacement Reinforcing Steel

In case of reinforcing steel which has 10% or more section losses due to the corrosion, additional or replacement reinforcing steel shall be provided as instructed by the Engineer. Replacement of reinforcing steel shall be cleaned to the same standard as the existing ones. This replacement reinforcing steel shall be lapped on the side of the existing bars and should be spot welded on one side. It shall be fixed along its length at suitable intervals to prevent sagging. The corroded reinforcing steel shall be cleaned and applied with anti-corrosive paint to prevent further corrosion.

9.) Applying Primer to Concrete and Anti-Corrosive Paint to Reinforcing Steel

Concrete surface shall be saturated with clean low pressure water for a minimum of 2 hours before application ensuring that all pores and pits are adequately wet. The surface shall not be allowed to dry before application.

Primer is applied to clean concrete surfaces in order to bond firmly. With a brush working vigorously to ensure that they are evenly covered all around. In case, the condition of the substrate of existing concrete is dry when applying repair material, there is the possibility of occurrence of dry out phenomenon. It occurs when water in repair material will be absorbed by existing concrete and which will induce restraint of hydration reaction and this phenomenon cause hardening or adhesive failure. Application of the primer (water absorption adjustment material) on substrate of the concrete will prevent the occurrence of dry out phenomenon.

Moisture condition of base surface before application of primer shall be in accordance with data

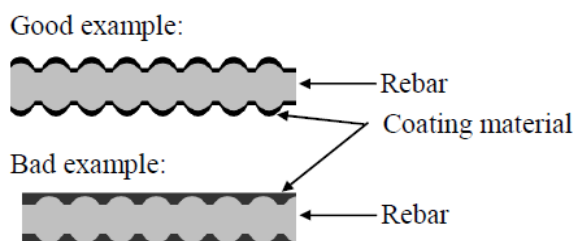
sheet. In case that the usage of primer is not adhered to due to misconception, bonding strength might be lower than what is achieved with the application of primer.

Applying Anti Corrosive Paint (Zinc rich primer / Polymer cement / Epoxy resin) to Reinforcing Steel
Surface shall be cleaned

The reinforcing steel should be blasted or wire blasted (Power or Hand tool) to remove all traces of corrosion and surface should be dry.

No matter the paint used is single or two components, mix thoroughly until a uniform consistency is reached, since the epoxy based zinc rich paint is precipitated before using. Continue to stir the mixture periodically during the application to avoid precipitation.

When applying anti corrosive paint on reinforcing steel, it is necessary to keep the surface evenly as shown below.



10.) Filling up Repair Material

Generally, the repair material should be placed in layers of about 20mm thickness. The maximum thickness for one layer shall be in accordance with data sheet. Compact each layer thoroughly over the entire surface using a wooden or steel trowel.

Generally, there should be no delays (time) between the placing and compacting of layers. The plastering to the surrounding concrete is performed using a form material, and then using a wood float or steel trowel. The repair material shall be mixed using equipment (normally a hand mixer) approved by the Engineer.

The water shall be added to the dry components and thoroughly mixed to achieve a uniform mixture (viscosity), unless otherwise approved by the Engineer. The repair material shall then be applied to the bonding agent using hand packing and trowel to the satisfaction of Engineer in charge. The textured finish of the final repair mortar layer shall match the finish on the existing interior surface.

The repair mortar application shall be built up to the original surface profile in layers not exceeding 20mm and the final layer shall not exceed 15mm, unless otherwise recommended by the manufacturer and approved by the Engineer in charge.

11.) Curing

Variety of repair materials are in need of continuous curing to develop strength and impermeability, and to minimize drying shrinkage while bond strength is developing. Curing of the repair mortar shall be in accordance with the polymer modified additive manufacturer's instructions.

Where curing agents are specified by manufacturer, they shall be applied immediately after the surface is available for the next repair of mortar layer or troweled to a finish.

Avoid direct sunlight during curing by means of sheet or boards.

12.) Visual and Audio Check

After repaired part get hardened, strike it with the hammer to detect from the sound emanates to make sure that separation does not occur.

2. Material Specification

1.) Specification

Specification of material for repair work by plastering method is shown in following table.

Table 2.1 Specification of repair material for structural and Non-Structural

Item	Requirement			
	Structural		Non-Structural	
	Class R4	Class R3	Class R2	Class R1
Compressive Strength	$\geq 45\text{MPa}$	$\geq 25\text{MPa}$	$\geq 15\text{MPa}$	$\geq 10\text{MPa}$
Chloride Ion Content	$\leq 0.05\%$		$\leq 0.05\%$	
Adhesive Bond	$\geq 2.0\text{MPa}$	$\geq 1.5\text{MPa}$	$\geq 0.8\text{MPa}$	
Restrained shrinkage Expansion	Max average crack width $< 0.05\text{mm}$ No crack width $> 0.1\text{mm}$ No delamination			No requirement
	$\geq 2.0\text{MPa}$	$\geq 1.5\text{MPa}$	$\geq 0.8\text{MPa}$	
DURABILITY Carbonation Resistance (not required if coated)	$dk \leq \text{Control concrete C(0.45)}$			Not requirement
Elastic Modulus	$\geq 20\text{GPa}$	$\geq 15\text{GPa}$	Not required	

※Extracting from BS EN 1504-3

Table 2.2 Specification of Epoxy Bonding Agent to concrete surface

Item	Test Method	Specification
Compressive strength	ASTM D695M	70N/mm^2
Flexural strength	ASTM D790M	40N/mm^2
Tensile strength	ASTM D638M	30N/mm^2
Tensile shear bond to steel	ASTM 1002	15N/mm^2
Slant shear bond to mortar	ASTM C882	15N/mm^2
Bond strength of cured concrete to fresh concrete	ASTM D7274	15N/mm^2

Table 2.3 Specification of Zinc Rich Primer for reinforcing steel

Item	Test Method	Specification
Adhesion	ASTM D3359	Minimum rating : 3A
Salt spray resistance	ASTM D3-37	Excellent

Table 2.4 Specifications of water for mixing repair material













Classification	NOTE
Potable water	
Water recovered from processed in the concrete industry or combined water	Need to check Annex A of BS EN1008
Water from underground sources or natural surface water and industrial waste water	Need to check Annex B of BS EN1008





※Extracting from BS EN1008

3. Equipment list

General equipment and tools need for plastering method are shown in following table.

Table 3.1 Equipment list

1.Preparatory inspection and clean the surface		
Hand brush	Air blower	Hammer
		
2.Making cut line and saw cut		
Tape	Chalk	Power disc cutter
		
3.Removal of defective concrete surface treatment for reinforcing steel		
Chisel	Electric pick hammer	Hammer
		
Wire brush	Electric wire brush	Air blower
		

4. Preparation of repair material and mixing		
Hand mixer	Measure cup	Weight measuring apparatus
		
Pail can		
		
5.Setting repair material		
Steel trowel	Panel for repair material	Brush
		
6.Others		
Portable generator	Curing sheet	Cloth
		

4. Storage and Shelf Life

The requirement of storage and shelf life shall be in accordance with data sheet.

General requirement of the repair materials are as follow.

- Material can be kept for 12 months if store in original unopened bags in cool and dry warehouse conditions. Generally, refer to material data sheet.
- Keep away from direct sunlight and rainfall.
- Unopened and undamaged sealed packing in dry condition at temperatures between +5 centigrade and 30 centigrade.
- Avoid excessive compaction.
- Utilize the opened bags to the fullest.
- Clearance from the ground level for pallets to be protected from rainfall.

5. Quality Control

1) Standard check items for before, during and after preparation of repair work

General tests shown in following table are purposed to confirm the condition of repair material, ambient and substrate of structure before, during and after preparation of conducting repair work. Some tests may be omitted when assessment result of below contents are satisfied.

Table 5.1 Items of Quality Control (Before, during and after preparation)

Characteristic	Reference	Frequency	Parameters
Temperature (ambient and substrate)	Record	During application	Within Product Data Sheet limits
Ambient Humidity	Record	During application	Within Product Data Sheet limits
Precipitation	Record	During application	Keep records and provide protection
Packaging	Visual	Every bag	No damage
Dry Product aspect	Visual	2 bags per 10	Loose, no lumps and not compacted
Mixed material	Visual	Every mix	Homogeneous, no lumps no un-mixed dry powder
Cleanliness of Concrete	Visual	After preparation and immediately before application	No contamination, loose particles or defects
Cleanliness of Steel Bars	EN ISO8501-1	After preparation and immediately before application	No rust, scale or contamination (Grade Sa 2 or Sa 2 _{1/2})
Delaminating Concrete	Hammer Sounding	After preparation	No delamination concrete
Roughness	Visual or EN 1766 on horizontal surfaces	After preparation	Minimum roughness 2mm(repair area) No laitance layer(smoothing mortars)
Surface Tensile Strength of the Substrate	EN 1542	After preparation works	>1.0N/mm ² for structural repair

2) Standard check items after completion of repair work

General tests shown in following table are proposed to confirm the status after completion of repair work.

Table 5.2 Items of Quality Control (After completion)

Characteristic	Reference	Frequency	Parameters
Crack	Visual	28 days after application	No crack on application section
Presence of Voids / Delaminating	EN 12504-1 Hammer sounding or ultrasonic testing	After application	No delaminating on application section

6. Inspection Sheet and Repair Record

Repair result shall be recorded such as as-built drawings, inspection sheets, investigation reports, repair design report, construction scene photograph and method statement.

As for the inspection sheets are shown in following table.

Table 6.1 Inspection sheet (1)

Inspection sheet(1)						
Client	:					
Consultant	:					
Contractor	:					
INSPECTION OF MATERIAL						
INSPECTION DATE	:					
BRIDGE / STRUCTURE NAME	:					
1.Main materials						
Materials	Description	Name / source	Expire date			
Cement	<input type="checkbox"/> Ready mixed					
	<input type="checkbox"/> Ordinary Portland cement					
	<input type="checkbox"/> Early strength Portland cement					
	<input type="checkbox"/> Ultra early strength Portland cement					
	<input type="checkbox"/> Others					
Aggregate	<input type="checkbox"/> ≤ mm					
Fiber	<input type="checkbox"/> Steel / Organic					
Admixture	<input type="checkbox"/> Polymer					
	<input type="checkbox"/> Quick setting agent					
	<input type="checkbox"/> Ultra fine powder					
	<input type="checkbox"/> Others					
2.Other materials						
Materials	Description	Name / source	Expire date			
Primer	<input type="checkbox"/>					
Curing comp.	<input type="checkbox"/>					
	<input type="checkbox"/>					
3.Purchased Quantity						
Materials	Mode of packing	Unit	Quantity	Total Amount	Condition	Mill sheet
Cement						
Aggregate						
Fiber						
Admixture						
Primer						
Curing comp.						
4.Note						
<hr/>						
5.Judgment						
<input type="checkbox"/> Accepted <input type="checkbox"/> Not Accepted						
	The contractor	The Consultant	The Client			
	Signature :	Signature :	Signature :			
	Name :	Name :	Name :			

Table 6.2 Inspection sheet (2)

Inspection sheet(2)					
Client : _____					
Consultant : _____					
Contractor : _____					
INSPECTION OF MATERIAL					
INSPECTION DATE : _____					
BRIDGE / STRUCTURE NAME : _____					
1.Quantity Table					
Repair Area in Contract					
No.	Length (m)	Width (m)	Area (m ²)	Repair method	
1					
2					
3					
Actual Area Removed (Accepted for payment)					
No.	Length (m)	Width (m)	Depth (m)	Area (m ²)	Repair method
1					
2					
3					
2.Sketch					
3.Concrete surface,Edge					
Item	Check				
Feather edge	<input type="checkbox"/> NG	<input type="checkbox"/> OK : No feather edge exists			
Concrete edge	<input type="checkbox"/> NG	<input type="checkbox"/> OK : Saw cut(about 10mm) is made at the concrete edge			
Concrete surface	<input type="checkbox"/> NG	<input type="checkbox"/> OK : Base surface to be filled is appropriately roughen			
Overhang	<input type="checkbox"/> NG	<input type="checkbox"/> OK : No overhang which cause problem of concrete filling			
4.Remarks					
5.Judgement					
<input type="checkbox"/> Accepted <input type="checkbox"/> Not Accepted					
	The contractor	The Consultant	The Client		
	Signature :	Signature :	Signature :		
	Name :	Name :	Name :		

Table 6.3 Inspection sheet (3)

Inspection sheet(3)			
Client	:		
Consultant	:		
Contractor	:		
INSPECTION OF MATERIAL			
INSPECTION DATE	:		
BRIDGE / STRUCTURE NAME	:		
1. Steel bar			
Items	Description	Judge	
		OK	NG
Corrosion removed by	<input type="checkbox"/> Sand blast <input type="checkbox"/> Other method		
Existence of corrosion	Harmful corrosion is removed		
Additional steel bar	Arranged or not required		
Splicing / fixation of steel bar	Firmly fixed		
Spacing of steel bar	Sufficient spacing for repair material filling		
2. Anti-corrosion primer			
a. Necessity of application		<input type="checkbox"/> Required <input type="checkbox"/> Not required	
b. Product name and component			
Product name	Comp.A (Liquid, Powder)	Comp.B (Liquid, Powder)	
c. Standard coverage			
for			
d. Quantity used			
Plan			
Actual			
Difference			
e. Application			
Items	Judge		
	OK	NG	
Quantity			
Visual			
3. Note			
4. Judgement			
<input type="checkbox"/> Accepted <input type="checkbox"/> Not Accepted			
	The contractor	The Consultant	The Client
	Signature :	Signature :	Signature :
	Name :	Name :	Name :

Table 6.4 Inspection sheet (4)

Inspection sheet(4)							
Client :							
Consultant :							
Contractor :							
INSPECTION OF MATERIAL							
INSPECTION DATE :							
BRIDGE / STRUCTURE NAME :							
1.Mix Propotion of repair material							
<input type="checkbox"/> Site mix							
Material	W / C	Cement	Water	Aggregate	Admixture1	Admixture2	
Amount							
<input type="checkbox"/> Ready mixed							
2.Primer <input type="checkbox"/> Use <input type="checkbox"/> Do not use (Is substrate sartuation confirmed?)							
Product name		Comp.A (Liquid, Powder)			Comp.B (Liquid, Powder)		
3.Mixing of repair material							
Batch No.	Mixing Equipment		Weight / Volume				
	OK	NG	Cement ()	Water ()	Aggregate ()	Admixture ()	Admixture ()
1	<input type="checkbox"/>	<input type="checkbox"/>					
2	<input type="checkbox"/>	<input type="checkbox"/>					
3	<input type="checkbox"/>	<input type="checkbox"/>					
Batch No.	Mix time(min)		Judge		Note		
	Start	End					
		hh mm	hh mm	OK	NG		
1							
2							
3							
4.Application / casting / spraying							
Batch No.	Equipment		Application time(min)		Temperature	Judge	
	OK	NG	Start	End		OK	NG
				hh mm	hh mm		
1	<input type="checkbox"/>	<input type="checkbox"/>					
2	<input type="checkbox"/>	<input type="checkbox"/>					
3	<input type="checkbox"/>	<input type="checkbox"/>					
4.Note							
5.Judgement							
<input type="checkbox"/> Accepted <input type="checkbox"/> Not Accepted							
		The contractor		The Consultant		The Client	
		Signature :		Signature :		Signature :	
		Name :		Name :		Name :	

Table 6.5 Inspection sheet (5)

Inspection sheet(5)			
Client	:		
Consultant	:		
Contractor	:		
INSPECTION OF MATERIAL			
INSPECTION DATE	:		
BRIDGE / STRUCTURE NAME	:		
1.Curing			
Item	Description	Check	
		OK	NG
Curing method	Water spray / Water mat / Curing compound	<input type="checkbox"/>	<input type="checkbox"/>
Curing period	More not less than hrs	<input type="checkbox"/>	<input type="checkbox"/>
Wind protection	If required	<input type="checkbox"/>	<input type="checkbox"/>
Sunlight protection	If required	<input type="checkbox"/>	<input type="checkbox"/>
	If required	<input type="checkbox"/>	<input type="checkbox"/>
2.Visual Inspection			
Item	Check		Note
	OK	NG	
Dimensions	<input type="checkbox"/>	<input type="checkbox"/>	
Roughness	<input type="checkbox"/>	<input type="checkbox"/>	
Existance of loosing material	<input type="checkbox"/>	<input type="checkbox"/>	
Color	<input type="checkbox"/>	<input type="checkbox"/>	
Cracks	<input type="checkbox"/>	<input type="checkbox"/>	
	<input type="checkbox"/>	<input type="checkbox"/>	
3.Physical Inspection			
Item	Check		Note
	OK	NG	
Sounding (hammer) test	<input type="checkbox"/>	<input type="checkbox"/>	Required
Rebound hammer test	<input type="checkbox"/>	<input type="checkbox"/>	When required
4.Remark			
<div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; height: 15px; margin-bottom: 5px;"></div>			

7. Health and Safety

7.1. Risk Assessment

The risk to health and safety from falling objects or defects in the structure shall be properly assessed. Platforms and temporary structures shall provide a stable and safe area to work. Do not take any unnecessary risks.

7.2. Personal Protection

Handling or processing repair materials may generate dust which can cause mechanical irritation to the eyes, skin, nose and throat.

Appropriate eye protection shall be worn at all times while handling and mixing products.

Approved dust masks shall be worn to protect the nose and throat from dust.

Safety shoes, gloves and other appropriate skin protection shall be worn at all times.

Always wash hands with suitable soap after handling products and before food consumption

Table 7.1 List of safety equipment

Eye protection	Gloves	Helmet	Dust masks
			
Work wear	Safety shoes	Safety vest	Safety belt
			
Soundproofing earplugs			
			

7.3. First Aid

Seek immediate medical attention in the event of excessive inhalation, ingestion or eye contact causing irritation. Do not induce vomiting unless directed by medical personnel.

Flush eyes with plenty of clean water occasionally lifting upper and lower eyelids. Remove contact lenses immediately. Continue to rinse eye for 10 minutes and then seek medical attention. Rinse contaminated skin with plenty of water. Remove contaminated clothing and continue to rinse for 10 minutes and seek medical attention.

For detailed information refer to the material safety data sheet.

7.4. Traffic control

If the repair work will be conducted under open traffic, the inspectors shall pay attention to provide safety for vehicles and pedestrians. Flagmen and safety cones must be placed to notice the working site to vehicles / pedestrians. The work shall be complied with all relative law / regulations in Sri Lanka.

Attachment 2 - Cleaning the Surface of Steel Members

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1. Work Description

During the serviceable life of a bridge, several components get dirty due to deposition of foreign materials. Materials that accumulate on the deck slab surface flows with the rain water towards the drainage spouts which may choke the outlets and affect proper drainage. Also the materials that accumulate on the deck and carried by the rain water towards the girder or expansion joint can pass through any opening present therein and accumulate on the pier cap, abutment caps and around the bearings. Such accumulation can cause malfunctioning of the girder or bearings since debris tend to hold water and lead to generate corrosion. Also growth of vegetation such as grass, shrubs and other plants on the components of bridge equally affect the smooth functioning of those components.

Various components of the bridge, namely deck surface, curb and side walk, expansion joints, pier caps, abutment caps, trusses and their web members, lower flanges of beams and girder, wind bracing and drains shall be thoroughly cleaned from accumulated dust, debris and other foreign materials at regular intervals. It will prevent the deterioration of the bridge, which will help to preserve the bridge components in their original conditions and extend the service life of the bridge as well as provide safety and comfort to the road users. Areas which have been cleaned should be protected from accumulated sand, gravel, dirt, and other foreign materials. Therefore, the vegetation grown on the components of bridges and near the bridges and vegetation near the bridges that obstruct the natural flow of water underneath the bridges shall be removed.

2. Work Sequence and Requirement

2.1. Work sequence

Work flow for cleaning the steel surface due to debris accumulation is shown below.

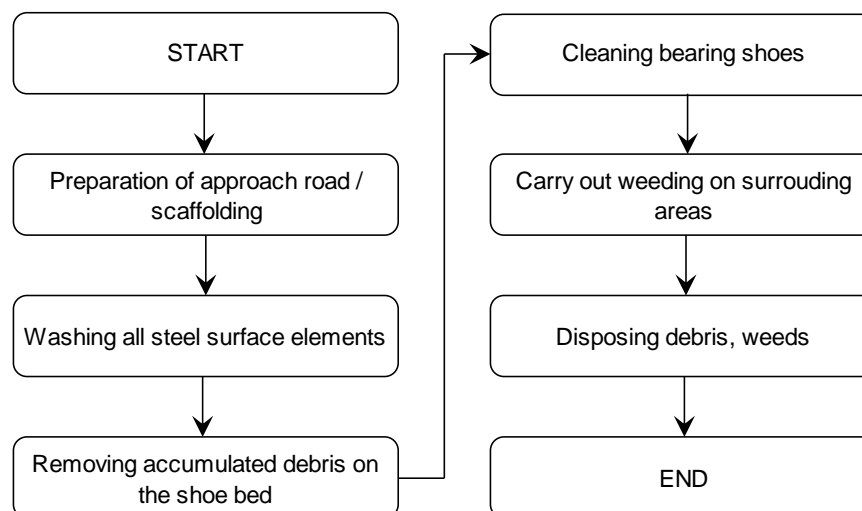


Figure 2.1 Work Flow of Cleaning the Surface of Steel Member

Table 2.1 Reference photos

Preparing high pressure water blasting machine	Preparing water tank
	
Cleaning surface using scraper	Cleaning surface using high pressure water blasting machine
	

2.2. Work Requirement

2.2.1. General

All accumulated foreign materials shall be removed from bridge sidewalks, bridge decks, top of curbs, beam flanges, gusset plates, abutment bridge seats, top of pier, truss joints, deck drain systems, and other locations specified and as directed by the Engineer, prior to cleaning with water pressure equipment. Removal shall be performed using hand brooms, hand shovels, scrapers, vacuum cleaners or other methods acceptable to the Engineer. The removed materials shall be collected and disposed at an approved waste area in accordance with prevailing local regulations.

2.2.2. High Pressure Water

Salt contaminants, dirt, and other detrimental foreign matters shall be removed without damaging or peeling the paint from any steel structure. If high-pressure water is used, the maximum water pressure shall be within the limits to prevent the damage of paint. The cleaning operation shall be discontinued if the foreign materials have not been easily removed or if cleaning operation is causing damage to existing paint coating. In this situation, the high pressure water shall be adjusted to clean the surface without damaging the paint coating.

All deck drains and its accessories shall be flushed with high pressure water after accumulated foreign material have been properly removed. Drainage system may have to be disassembled to remove large blockage of accumulated foreign material. Should this be necessary, the system shall be reassembled to their original configuration immediately after cleaning and checked whether the system is operating properly.

The high pressure water jet shall be used to flush out the interior surface of all girders and truss members until clear water comes out from the other end.

The exterior surface of all truss members, miscellaneous structural steel connecting the truss members, and floor beam ends projecting outwardly from the row of exterior stringers shall be thoroughly washed using high pressure water.

The source of water used for cleaning purposes shall be an approved one. The water should also be free from sediments and salt contaminants and the expenses involved in securing the approval for the quality of water to be used will be the responsibility of the entrusted body if the activity is outsourced.

3. Application Criteria

Criteria for cleaning applied to the bridge including its steel surface, deck and substructure are recommended below:

3.1. Surface of Steel Plate

The surface of steel bridge should be cleaned and washed by brushing with fresh water or using high water blasting, including the top and bottom flanges, web plates, diaphragms, lateral members and gusset plate. For convenience, inspection vehicle may be utilized to carry out cleaning of the bridge soffit.

3.2. Bridge Deck Slab

All surface areas of the bridge deck should be cleaned including the curbs, expansion joints, drain pits and railing. This may be performed by manual shoveling / sweeping or using high pressure water blasting.

3.3. Bridge Substructure

All areas under the superstructure should be cleaned, including the bearing bed, concrete diaphragms and pier caps. This may be done by manual shoveling / sweeping or using high pressure water blasting. For accessing the top of piers, a high ladder or hang ladder will be useful and an inspection vehicle can be utilized, if possible.

4 Required Material and Tools / Equipment

1). Required Materials

Freshwater suitable for cleaning

Water to be used for cleaning of the bridge components shall be clean and free from unwanted foreign materials such as sediments, salt contaminants, chemicals, grease, oil, rubbish and other substance, which are harmful to the bridge components.

Engineer's approval shall be taken on the source and quality of water. All necessary tests shall be performed on water samples at laboratories to be specified by the Engineer, and test certificates shall be provided as required.








The water should be pH Value between 7 – 8 with Conductivity level below 60 μ s / m.

In general following water quality is appropriate to use.

- Potable water
- Water recovered from processes in concrete industry
- Water from underground sources
- Natural surface water and industrial waste water (Necessary to be tested)

2). Required Tools / Equipment

Table 2.2 Equipment list

Hand Shovel	Hand Brush	Wire Brush
		
Scraper		
		
High Pressure Water Blasting Machine (Water Pressure 5MPa – 20MPa)	Water Tank	Portable Generator
		

Attachment 3 - Specification for Zone Painting

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1. Work Description

1) Introduction

Due to thin paint coating on steel surfaces, the steel surface may be exposed to atmosphere resulting in accumulation of corrosion. Zone painting at the early stage of paint degradation or corrosion prevents further deterioration.

Work included in this section comprises field zone painting on steel members at localized areas including surface preparation and other associated works. This covers only painting on relatively small affected areas which can be carried out with the use of small power tools/ hand tools. Painting for large areas required blast cleaning for surface treatment and should be carried out with detail work plan in accordance with ISO-12944.

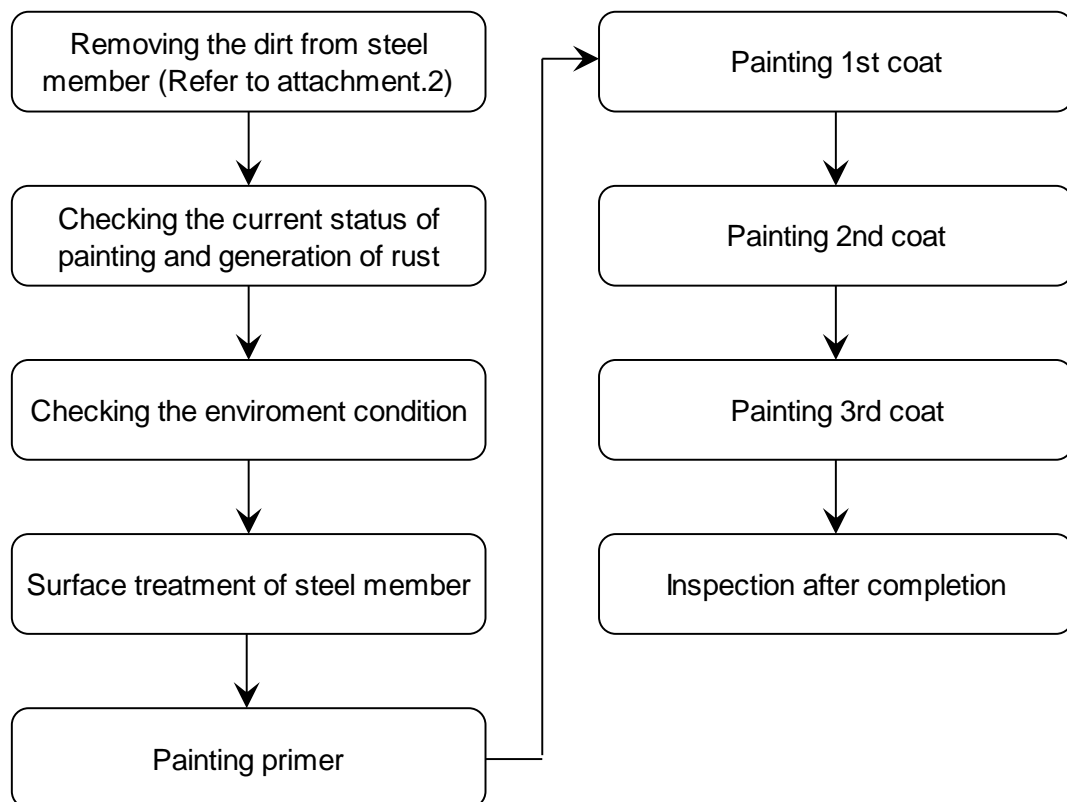







Figure 1.1 Work flow of zone painting

Table 1.1 Reference Photos of Surface Treatment

1.Setting scaffolding	2. Removing the tar applied on the girder using scraper. This procedure shall be conducted before surface cleaning using high pressure water.	3. Removing the tar applied on the girder by hammer tapping. This procedure shall be conducted after surface cleaning using high pressure water.
		
4. Conducting surface treatment using electric cup-wire brush or power disc grinder.	5.After completion of surface treatment at one part (The part surrounded by red line is the completed area for surface treatment)	
		

※ Procedure 3 is necessary in case tar was applied on surface of the steel member. They shall be removed by hammer tapping or scraper before conducting surface treatment by electric cup-wire brush or power disc grinder. Otherwise, the tar will be melted by friction heat by electric cup-wire brush or power disc grinder and adhering to them.

2. Design Conditions

2.1. Classification of Durability and Environment

It is necessary to decide the classification of durability of the coating and environment of the bridge's location in accordance with ISO12944-1 and ISO12944-2 to decide the coating system. The definition of durability range is different from "guarantee duration". Durability is a technical consideration that can help the RDA to set up a maintenance plan. A guarantee time is the subject of clauses in the contract and is not within the scope of this part of ISO 12944. There are no rules that link the two periods of time.

Classification of durability of coating and environment are shown in the following Table.

Table 2.1 Classification of Durability

Durability	Durability Range
Low (L)	2 years to 5 years
Medium (M)	5 years to 15 years
High (H)	More than 15 years

※Extracting from ISO12944-1

Table 2.2 Classification of Environment

Environmental Category		Description
C1	Very low	Rural Areas, Low pollution, Dry & Neutral atmospheres
C2	Low	Unheated Building, Possible condensation
C3	Medium	Urban atmospheres, Moderate SO ₂ pollution
C4	High	Industrial and Coastal
C5 I	Very high Industrial	Industry with high humidity and adverse atmospheres
C5 M	Very high marine	Marine coastal, offshore high salinity

※ Extracting from ISO12944-2

Table 2.3 Atmospheric and corrosivity category and example of typical environment

Corrosivity category	Mass loss per unit surface/thickness loss (after first year of exposure)				Examples of typical environments in a temperate climate (informative only)	
	Low-carbon steel		Zinc		Exterior	Interior
	Mass loss g/m ²	Thickness loss μm	Mass loss g/m ²	Thickness loss μm		
C1 very low	≤ 10	≤ 1,3	≤ 0,7	≤ 0,1	—	Heated buildings with clean atmospheres, e.g. offices, shops, schools, hotels.
C2 low	> 10 to 200	> 1,3 to 25	> 0,7 to 5	> 0,1 to 0,7	Atmospheres with low level of pollution. Mostly rural areas.	Unheated buildings where condensation may occur, e.g. depots, sports halls.
C3 medium	> 200 to 400	> 25 to 50	> 5 to 15	> 0,7 to 2,1	Urban and industrial atmospheres, moderate sulfur dioxide pollution. Coastal areas with low salinity.	Production rooms with high humidity and some air pollution, e.g. food-processing plants, laundries, breweries, dairies.
C4 high	> 400 to 650	> 50 to 80	> 15 to 30	> 2,1 to 4,2	Industrial areas and coastal areas with moderate salinity.	Chemical plants, swimming pools, coastal ship- and boatyards.
C5-I very high (industrial)	> 650 to 1 500	> 80 to 200	> 30 to 60	> 4,2 to 8,4	Industrial areas with high humidity and aggressive atmosphere.	Buildings or areas with almost permanent condensation and with high pollution.
C5-M very high (marine)	> 650 to 1 500	> 80 to 200	> 30 to 60	> 4,2 to 8,4	Coastal and offshore areas with high salinity.	Buildings or areas with almost permanent condensation and with high pollution.
NOTES						
1 The loss values used for the corrosivity categories are identical to those given in ISO 9223.						
2 In coastal areas in hot, humid zones, the mass or thickness losses can exceed the limits of category C5-M. Special precautions must therefore be taken when selecting protective paint systems for structures in such areas.						

※ Extracting from ISO12944-2

2.2. Surface Treatment Grade

The primary purpose of surface treatment is to ensure the removal of deleterious matter and to obtain a surface that permits satisfactory adhesion of priming paint to the steel. It shall be in accordance with ISO8501-1. It will also assist in reducing the amounts of contaminants that initiate corrosion.

Surface treatment grade are shown in following table.

Table 2.4 Standard Grades for Surface Treatment

Standard preparation grade ¹⁾	Surface preparation method	Representative photographic examples in ISO 8501-1 ^{2) 3) 4)}	Essential features of prepared surfaces For further details, including treatment prior to and after surface preparation (column 2), see ISO 8501-1.	Field of application
Sa 1	Blast-cleaning (6.2.3)	B Sa 1 C Sa 1 D Sa 1	Poorly adhering mill scale, rust and paint coatings and foreign matter are removed. ⁵⁾	The surface preparation of a) uncoated steel surfaces; b) coated steel surfaces, if the coatings are removed to the extent that the specified preparation grade is achieved. ⁶⁾
Sa 2		B Sa 2 C Sa 2 D Sa 2	Most of the mill scale, rust, paint coatings and foreign matter is removed. Any residual contamination shall be firmly adhering.	
Sa 2½		A Sa 2½ B Sa 2½ C Sa 2½ D Sa 2½	Mill scale, rust, paint coatings and foreign matter are removed. Any remaining traces of contamination shall show only as slight stains in the form of spots or stripes.	
Sa 3 ⁷⁾		A Sa 3 B Sa 3 C Sa 3 D Sa 3	Mill scale, rust, paint coatings and foreign matter are removed. The surface shall have a uniform metallic colour.	
St 2	Hand- or power-tool cleaning (6.2.1, 6.2.2)	B St 2 C St 2 D St 2	Poorly adhering mill scale, rust, paint coatings and foreign matter are removed. ⁵⁾	
St 3		B St 3 C St 3 D St 3	Poorly adhering mill scale, rust, paint coatings and foreign matter are removed. ⁵⁾ However, the surface shall be treated much more thoroughly than for St 2 to give a metallic sheen arising from the metal substrate.	
Fl	Flame cleaning (6.3)	A Fl B Fl C Fl D Fl	Mill scale, rust, paint coatings and foreign matter are removed. Any remaining residues shall show only as a discoloration of the surface (shades of different colours).	⁶⁾
Be	Acid pickling (6.1.8)		Mill scale, rust and residues from paint coatings are removed completely. Paint coatings shall be removed prior to acid pickling by suitable means.	Prior to hot-dip-galvanizing, for example.
<p>1) Key to symbols used: Sa = blast-cleaning (ISO 8501-1) St = hand-tool or power-tool cleaning (ISO 8501-1) Fl = flame cleaning (ISO 8501-1) Be = acid pickling</p> <p>2) A, B, C and D are initial conditions of uncoated steel surfaces (see ISO 8501-1).</p> <p>3) The representative photographic examples show only surfaces or surface areas that were previously uncoated.</p> <p>4) In the case of steel surfaces with painted or unpainted metal coatings, an analogous application of certain standard preparation grades may be agreed, provided that these are technically feasible under the given conditions.</p> <p>5) Mill scale is considered to be poorly adhering if it can be removed by lifting with a blunt putty knife.</p> <p>6) The factors influencing assessment shall be given particular consideration.</p> <p>7) This surface preparation grade can only be achieved and maintained under certain conditions which it may not be possible to produce on site.</p>				


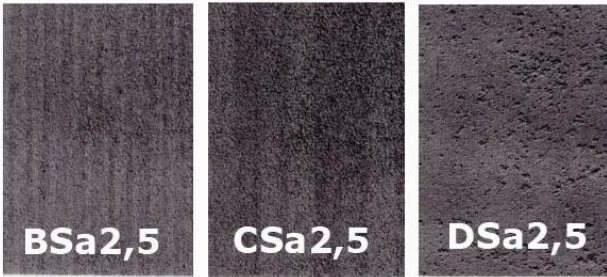
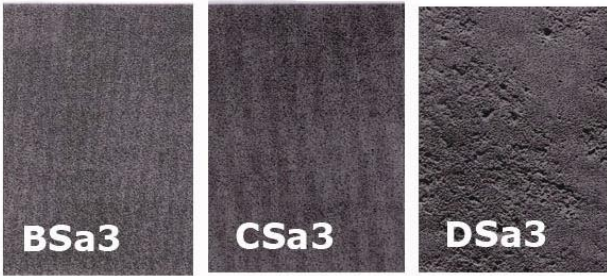
Table 2.5 Standard grades of surface treatment

Standard preparation grade ¹⁾	Surface preparation method	Representative photographic examples in ISO 8501-1 or ISO 8501-2 ^{2) 4) 6)}	Essential features of prepared surfaces For further details, including treatment prior to and after surface preparation (column 2), see ISO 8501-2.	Field of application
P Sa 2 ³⁾	Localized blast-cleaning	B Sa 2 C Sa 2 D Sa 2 (apply to uncoated parts of the surface)	Firmly adhering paint coatings shall be intact. ⁵⁾ From the surface of the other parts, loose paint coatings and most of the mill scale, rust and foreign matter are removed. Any residual contamination shall be firmly adhering.	The surface preparation of coated steel surfaces on which some paint coatings remain. ⁷⁾
P Sa 2½ ³⁾		B Sa 2½ C Sa 2½ D Sa 2½ (apply to uncoated parts of the surface)	Firmly adhering paint coatings shall be intact. ⁵⁾ From the surface of the other parts, loose paint coatings and mill scale, rust and foreign matter are removed. Any remaining traces of contamination shall show only as slight stains in the form of spots or stripes.	
P Sa 3 ^{3) 8)}		C Sa 3 D Sa 3 (apply to uncoated parts of the surface)	Firmly adhering paint coatings shall be intact. ⁵⁾ From the surface of the other parts, loose paint coatings and mill scale, rust and foreign matter are removed. The surface shall have a uniform metallic colour.	
P Ma ³⁾	Localized machine abrading	P Ma	Firmly adhering paint coatings shall be intact. ⁵⁾ From the surface of the other parts, loose paint coatings and mill scale, rust and foreign matter are removed. Any remaining traces of contamination shall show only as slight stains in the form of spots or stripes.	
P St 2 ³⁾	Localized hand- and power-tool cleaning	C St 2 D St 2	Firmly adhering paint coatings shall be intact. ⁵⁾ From the surface of the other parts, poorly adhering mill scale, rust, paint coatings and foreign matter are removed.	
P St 3 ³⁾		C St 3 D St 3	Firmly adhering paint coatings shall be intact. ⁵⁾ From the surface of the other parts, poorly adhering mill scale, rust, paint coatings and foreign matter are removed. However, the surface shall be treated much more thoroughly than for P St 2 to give a metallic sheen arising from the metal substrate.	
For footnotes, see next page.				




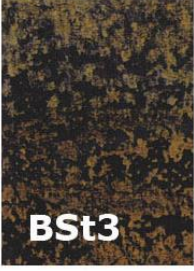


※ Extracting from ISO12944-4

The status of surface of steel member and reference photos after conducting surface treatment at each grade are shown in following table.

Table 2.6 Standard Grades of Surface Treatment and Reference Photos

Representative Photographic Examples in ISO8501-1 and ISO8501-2	Essential Features of Prepared Surface
ISO 12944-4 : P Sa 2 ISO 8501 : B Sa2, C Sa2, D Sa2 	Firmly adhering paint coating shall be intact. From the surface of the other parts, loose paint coatings and most of the mill scale, rust and foreign matter are removed. Any residual contamination shall be firmly adhering.
ISO 12944-4 : P Sa 2.5 ISO 8501 : B Sa2.5, C Sa2.5, D Sa2.5 	Firmly adhering paint coating shall be intact. From the surface of the other parts, loose paint coating and mill scale, rust and foreign matter are removed. Any remaining traces of contamination shall only as slight stains in the form of spots or stripes.
ISO 12944-4 : P Sa 3 ISO 8501 : B Sa3, C Sa3, D Sa3 	Firmly adhering paint coatings shall be intact. From the surface of the other parts, loose paint coating and mill scale, rust and foreign matter are removed. The surface shall have a uniform metallic color.

※ Extracting from ISO8501-2

Representative photographic examples in ISO8501-1 or ISO8501-2	Essential features of prepared surface
<p>ISO 12944-4 : P St 2 ISO 8501 : C St2, D St2</p> <div data-bbox="185 472 379 741">  <p>BSt2</p> </div> <div data-bbox="395 472 590 741">  <p>CSt2</p> </div> <div data-bbox="606 472 799 741">  <p>DSt2</p> </div>	<p>Firmly adhering paint coatings shall be intact. From the surface of the other parts, poorly adhering mill scale, rust, paint coating and foreign matter are removed.</p>
<p>ISO 12944-4 : P St 3 ISO 8501 : C St3, D St3</p> <div data-bbox="185 909 379 1178">  <p>BSt3</p> </div> <div data-bbox="395 909 590 1178">  <p>CSt3</p> </div> <div data-bbox="606 909 799 1178">  <p>DSt3</p> </div>	<p>Firmly adhering paint coatings shall be intact. From the surface of the other parts, poorly adhering mill scale, rust, paint coatings and foreign matter are removed. However, the surface shall be treated much more thoroughly than for P St2 to give a metallic sheen arising from the metal substrate.</p>

※ Extracting from ISO8501-2

2.3. Equipment for Surface Treatment

General necessary equipment need for each surface treatment are shown in the following table.

Table 2.7 Equipment for Surface Treatment

Surface Treatment Method	General Equipment
Hand tools cleaning	Chipping hammers, Spatulas, Hand scrapers, Hand wire brushes, Abrasive papers, Plastic fleece with embedded abrasives, Emery cloth
Power tool cleaning	Rotary de Scaler, Rotary wire brushes, Sanding machines, Sanding disc, Rotary abrasive-coated paper wheels (flap wheels), Abrasive grinders, Plastic fleece with embedded abrasives, Chipping hammers and needle guns, Percussion hammer
Blast cleaning	Centrifugal abrasive blast cleaning, Compressed air abrasive blast cleaning, Vacuum or suction head abrasive blast cleaning, Moisture injection abrasive blast cleaning, Compressed air wet abrasive blast cleaning, Slurry blast cleaning, Bristle Blaster※

※For reference

Equipment : Bristle Blaster

Advantage :

- Removes corrosion, coating, scale and adhesive residues
- Surface preparation grade comparable with SA 2.5 – 3 per ISO8501 - 1
- Roughness level of up to 120µm Rz
- ATEX –approved for use in Zone 1 (potentially explosive) atmospheres in accordance with Ex II 2G c II A T4 X
- Fast, flexible and cost – effective to use
- Eco – friendly and safe to use
- Ideal for spot – repairs, touch – up jobs and preparing welds

Bristle Blaster



2.4 Coating System (ISO12944-5)

The total film thickness shall be decided with consideration of durability range and environmental category of each bridge's location in accordance with ISO12944-1 and 12944-2.

The surface encountered in new structures are low-alloy steel of rust grade A, B and C as defined in ISO8501-1, as well as galvanized steel and metallized steel (see ISO 12944-1).

Possible surface treatment of the different substrates is described in ISO12944-4.

The recommended film thickness for each environmental category and durability range are shown in the following table.

Table 2.8 Recommended Film Thickness for Each Condition

Environmental Category	Durability Range	Recommended Film Thickness	Recommendation of area to apply
C1	Low	75μm	
	Medium	75μm	
	High	75μm	
C2	Low	80μm	
	Medium	150μm	
	High	200μm	
C3	Low	120μm	
	Medium	160μm	
	High	200μm	
C4	Low	160μm	
	Medium	200μm	
	High	240μm	
C5 I & C5 M	Low	200μm	
	Medium	280μm	
	High	320μm	

※ Extracting from ISO12944-5

The substrate and the recommended surface treatment grade are given in ISO12944-5 for each corrosive category. The coating system listed below are typical examples of systems used in the environmental defined in ISO 12944-2 when applied to steel surface with rust grade A to C, as defined in ISO8501-1, or to hot-dip-galvanized steel or metallized steel.

Where the steel has deteriorated to the extent that pitting corrosion has taken place (rust grade D in ISO 8501-1), the dry film thickness or the number of coats shall be increased in consideration of surface roughness.

Table 2.9 Coating systems for low-alloy carbon steel for corrosively category C2

Substrate: Low-alloy carbon steel										
Surface preparation: For Sa 2½ from rust grade A, B or C only (see ISO 8501-1)										
System No.	Priming coat(s)				Subsequent coat(s)	Paint system		Expected durability		
	Binder	Type of primer ^a	No. of coats	NDFT ^b in µm	Binder type	No. of coats	NDFT ^b in µm	Low	Med	High
A.2.01	AK	Misc.	1	40	AK	2	80			
A2.02	AK	Misc.	1-2	80	AK	2-3	120			
A2.03	AK	Misc.	1-2	80	AK, AY, PVC, CR ^c	2-4	160			
A2.04	AK	Misc.	1-2	100	—	1-2	100			
A2.05	AY, PVC, CR	Misc.	1-2	80	AY, PVC, CR ^c	2-4	160			
A2.06	EP	Misc.	1-2	80	EP, PUR	2-3	120			
A2.07	EP	Misc.	1-2	80	EP, PUR	2-4	160			
A2.08	EP, PUR, ESI ^d	Zn (R)	1	60 ^e	—	1	60			

Binder for priming coat(s)	Type	Water-borne possible	Binder for subsequent coat(s)	Type	Water-borne possible
AK = Alkyd	1-pack	X	AK = Alkyd	1-pack	X
CR = Chlorinated rubber	1-pack		CR = Chlorinated rubber	1-pack	
AY = Acrylic	1-pack	X	AY = Acrylic	1-pack	X
PVC = Poly(vinyl chloride)	1-pack		PVC = Poly(vinyl chloride)	1-pack	
EP = Epoxy	2-pack	X	EP = Epoxy	2-pack	X
ESI = Ethyl silicate	1- or 2-pack	X	PUR = Polyurethane, aliphatic	1- or 2-pack	X
PUR = Polyurethane, aromatic or aliphatic	1- or 2-pack	X			

^a Zn (R) = Zinc-rich primer, see 5.2. Misc. = Primers with miscellaneous types of anticorrosive pigments.

^b NDFT = Nominal dry film thickness. See 5.4 for further details.

^c It is recommended that compatibility be checked with the paint manufacturer.

^d It is recommended for ESI primers that one of the subsequent coats be used as a tie coat.

^e It is also possible to work with an NDFT from 40 µm to 80 µm provided the zinc-rich primer chosen is suitable for such an NDFT.

※ Extracting from ISO12944-5

Surface treatment grade		Surface treatment method
	St2, 3	Hand or Power cleaning
	Sa2, 3	Blast cleaning

Table 2.10 Coating systems for low-alloy carbon steel for corrosively category C3

Substrate: Low-alloy carbon steel											
Surface preparation: For Sa 2½ from rust grade A, B or C only (see ISO 8501-1)											
System No.	Priming coat(s)				Subsequent coat(s)		Paint system		Expected durability		
	Binder	Type of primer ^a	No. of coats	NDFT ^b in µm	Binder type		No. of coats	NDFT ^b in µm	Low	Med	High
A3.01	AK	Misc.	1-2	80	AK		2-3	120			
A3.02	AK	Misc.	1-2	80	AK		2-4	160			
A3.03	AK	Misc.	1-2	80	AK		3-5	200			
A3.04	AK	Misc.	1-2	80	AY, PVC, CR ^c		3-5	200			
A3.05	AY, PVC, CR ^c	Misc.	1-2	80	AY, PVC, CR ^c		2-4	160			
A3.06	AY, PVC, CR ^c	Misc.	1-2	80	AY, PVC, CR ^c		3-5	200			
A3.07	EP	Misc.	1	80	EP, PUR		2-3	120			
A3.08	EP	Misc.	1	80	EP, PUR		2-4	160			
A3.09	EP	Misc.	1	80	EP, PUR		3-5	200			
A3.10	EP, PUR, ESI ^d	Zn (R)	1	60 ^e	—		1	60			
A3.11	EP, PUR, ESI ^d	Zn (R)	1	60 ^e	EP, PUR		2	160			
A3.12	EP, PUR, ESI ^d	Zn (R)	1	60 ^e	AY, PVC, CR ^c		2-3	160			
A3.13	EP, PUR	Zn (R)	1	60 ^e	AY, PVC, CR ^c		3	200			

Binder for priming coat(s)	Type	Water-borne possible	Binder for subsequent coat(s)	Type	Water-borne possible
AK = Alkyd	1-pack	X	AK = Alkyd	1-pack	X
CR = Chlorinated rubber	1-pack		CR = Chlorinated rubber	1-pack	
AY = Acrylic	1-pack	X	AY = Acrylic	1-pack	X
PVC = Poly(vinyl chloride)	1-pack		PVC = Poly(vinyl chloride)	1-pack	
EP = Epoxy	2-pack	X	EP = Epoxy	2-pack	X
ESI = Ethyl silicate	1- or 2-pack	X	PUR = Polyurethane, aliphatic	1- or 2-pack	X
PUR = Polyurethane, aromatic or aliphatic	1- or 2-pack	X			

^a Zn (R) = Zinc-rich primer, see 5.2. Misc. = Primers with miscellaneous types of anticorrosive pigment.

^b NDFT = Nominal dry film thickness. See 5.4 for further details.

^c It is recommended that compatibility be checked with the paint manufacturer.

^d It is recommended for ESI primers that one of the subsequent coats be used as a tie coat.

^e It is also possible to work with an NDFT from 40 µm up to 80 µm provided the zinc-rich primer chosen is suitable for such an NDFT.

※ Extracting from ISO12944-5

Surface treatment grade	Surface treatment method	
	St2, 3	Hand or Power cleaning
	Sa2, 3	Blast cleaning

Table 2.11 Coating systems for low-alloy carbon steel for corrosively category C4

Substrate: Low-alloy carbon steel										
Surface preparation: For Sa 2½ from rust grade A, B or C only (see ISO 8501-1)										
System No.	Priming coat(s)				Subsequent coat(s)	Paint system		Expected durability		
	Binder	Type of primer ^a	No. of coats	NDFT ^b in µm	Binder type	No. of coats	NDFT ^b in µm	Low	Med	High
A4.01	AK	Misc.	1-2	80	AK	3-5	200			
A4.02	AK	Misc.	1-2	80	AY, CR, PVC ^c	3-5	200			
A4.03	AK	Misc.	1-2	80	AY, CR, PVC ^c	3-5	240			
A4.04	AY, CR, PVC	Misc.	1-2	80	AY, CR, PVC ^c	3-5	200			
A4.05	AY, CR, PVC	Misc.	1-2	80	AY, CR, PVC ^c	3-5	240			
A4.06	EP	Misc.	1-2	160	AY, CR, PVC ^c	2-3	200			
A4.07	EP	Misc.	1-2	160	AY, CR, PVC ^c	2-3	280			
A4.08	EP	Misc.	1	80	EP, PUR	2-3	240			
A4.09	EP	Misc.	1	80	EP, PUR	2-3	280			
A4.10	EP, PUR, ESI ^d	Zn (R)	1	60 ^e	AY, CR, PVC ^c	2-3	160			
A4.11	EP, PUR, ESI ^d	Zn (R)	1	60 ^e	AY, CR, PVC ^c	2-4	200			
A4.12	EP, PUR, ESI ^d	Zn (R)	1	60 ^e	AY, CR, PVC ^c	3-4	240			
A4.13	EP, PUR, ESI ^d	Zn (R)	1	60 ^e	EP, PUR	2-3	160			
A4.14	EP, PUR, ESI ^d	Zn (R)	1	60 ^e	EP, PUR	2-3	200			
A4.15	EP, PUR, ESI ^d	Zn (R)	1	60 ^e	EP, PUR	3-4	240			
A4.16	ESI	Zn (R)	1	60 ^e	—	1	60			

Binder for priming coat(s)	Type	Water-borne possible	Binder for subsequent coat(s)	Type	Water-borne possible
AK = Alkyd	1-pack	X	AK = Alkyd	1-pack	X
CR = Chlorinated rubber	1-pack		CR = Chlorinated rubber	1-pack	
AY = Acrylic	1-pack	X	AY = Acrylic	1-pack	X
PVC = Poly(vinyl chloride)	1-pack		PVC = Poly(vinyl chloride)	1-pack	
EP = Epoxy	2-pack	X	EP = Epoxy	2-pack	X
ESI = Ethyl silicate	1- or 2-pack	X	PUR = Polyurethane, aliphatic	1- or 2-pack	X
PUR = Polyurethane, aromatic or aliphatic	1- or 2-pack	X			

^a Zn (R) = Zinc-rich primer, see 5.2. Misc. = Primers with miscellaneous types of anticorrosive pigments.

^b NDFT = Nominal dry film thickness. See 5.4 for further details.

^c It is recommended that compatibility be checked with the paint manufacturer.

^d It is recommended for ESI primers that one of the subsequent coats be used as a tie coat.

^e It is also possible to work with an NDFT from 40 µm up to 80 µm provided the zinc-rich primer chosen is suitable for such an NDFT.

※ Extracting from ISO12944-5

Surface treatment grade		Surface treatment method
	St2, 3	Hand or Power cleaning
	Sa2, 3	Blast cleaning

Table 2.12 Coating systems for low-alloy carbon steel for corrosively category C5 – I and C5 - M

Substrate: Low-alloy carbon steel										
Surface preparation: For Sa 2½ from rust grade A, B or C only (see ISO 8501-1)										
System No.	Priming coat(s)				Subsequent coat(s)	Paint system		Expected durability		
	Binder	Type of primer ^a	No. of coats	NDFT ^b in µm	Binder type	No. of coats	NDFT ^b in µm	Low	Med	High
C5-I										
A5I.01	EP, PUR	Misc.	1-2	120	AY, CR, PVC ^c	3-4	200			
A5I.02	EP, PUR	Misc.	1	80	EP, PUR	3-4	320			
A5I.03	EP, PUR	Misc.	1	150	EP, PUR	2	300			
A5I.04	EP, PUR, ESI ^d	Zn (R)	1	60 ^e	EP, PUR	3-4	240			
A5I.05	EP, PUR, ESI ^d	Zn (R)	1	60 ^e	EP, PUR	3-5	320			
A5I.06	EP, PUR, ESI ^d	Zn (R)	1	60 ^e	AY, CR, PVC ^c	4-5	320			
C5-M										
A5M.01	EP, PUR	Misc.	1	150	EP, PUR	2	300			
A5M.02	EP, PUR	Misc.	1	80	EP, PUR	3-4	320			
A5M.03	EP, PUR	Misc.	1	400	—	1	400			
A5M.04	EP, PUR	Misc.	1	250	EP, PUR	2	500			
A5M.05	EP, PUR, ESI ^d	Zn (R)	1	60 ^e	EP, PUR	4	240			
A5M.06	EP, PUR, ESI ^d	Zn (R)	1	60 ^e	EP, PUR	4-5	320			
A5M.07	EP, PUR, ESI ^d	Zn (R)	1	60 ^e	EPC	3-4	400			
A5M.08	EPC	Misc.	1	100	EPC	3	300			

※ Extracting from ISO12944-5

Surface treatment grade		Surface treatment method
	St2, 3	Hand or Power cleaning
	Sa2, 3	Blast cleaning

Table 2.13 General properties of different generic types of paint















Suitability ■ Good ▲ Limited ● Poor — Not relevant	Poly(vinyl chloride) (PVC)	Chlorinated rubber (CR)	Acrylic (AY)	Alkyd (AK)	Polyurethane, aromatic (PUR, aromatic)	Polyurethane, aliphatic (PUR, aliphatic)	Ethyl zinc silicate (ESI)	Epoxy (EP)	Epoxy combination (EPC)
Gloss retention	▲	▲	▲	▲	●	■	—	●	●
Colour retention	▲	▲	■	▲	●	■	—	●	●
Resistance to chemicals:									
Water immersion	▲	■	▲	●	▲	●	▲	■	■
Rain/condensation	■	■	■	▲	■	▲	■	■	■
Solvents	●	●	●	▲	■	▲	■	■	▲
Solvents (splash)	●	●	●	■	■	■	■	■	■
Acids	▲	■	▲	▲	■	▲	●	▲	■
Acids (splash)	■	■	▲	▲	■	■	●	■	■
Alkalies	▲	▲	▲	▲	▲	▲	●	■	■
Alkalies (splash)	■	■	▲	▲	■	■	●	■	■
Resistance to dry heat:									
up to 70 °C	●	●	▲	■	■	■	■	■	■
70 °C to 120 °C	—	—	▲	■	■	■	■	■	▲
120 °C to 150 °C	—	—	▲	●	▲	●	■	▲	▲
> 150 °C but ≤ 400 °C	—	—	—	—	—	—	■	—	—
Physical properties:									
Abrasion resistance	●	●	●	▲	■	▲	■	■	▲
Impact resistance	▲	▲	▲	▲	■	▲	▲	■	▲
Flexibility	■	■	■	▲	▲	■	●	▲	▲
Hardness	▲	▲	▲	■	■	▲	■	■	■

※ Extracting from ISO12944-5

3. Equipment

General tools and equipment for zone painting are shown in following table.

Table 3.1 Equipment lists

1.Cleaning steel surface		
Hand brush	Wire brush	Scraper
		
Air blower	Hammer	
		
2.Surface treatment		
Wire brush	Electric cup wire brush	Power disc grinder
		
Bristle Blaster	Air blower	Needle hammer
		
3.Mixing paint		
Measure cup	Can	Hand mixer
		

4.Painting		
Woolen brush roller	Porous Brush roller	Spray gun
		
Brush	Roller bucket	
		
5.Measuring instrument		
Measuring temperature and relative humidity	Measuring temperature of steel surface	Measuring thickness of coating
		
6.Others		
Portable generator	Cloth	Tape
		
Curing sheet		
		

4. Quality Control

4.1. Standard check items for the current status of painting and rust

➤ Status of rust on the existing painting

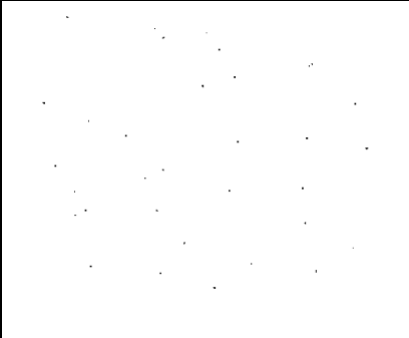

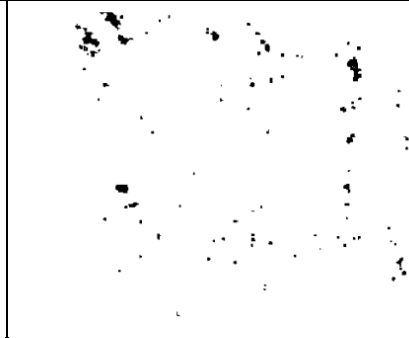
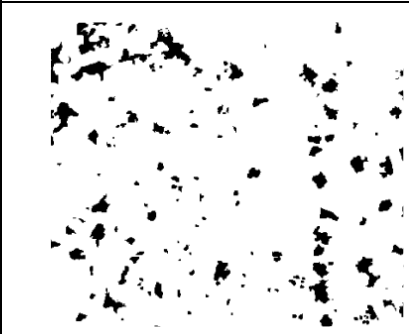
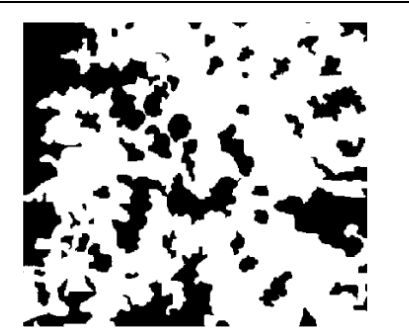
ISO4628-3 Paints and varnish – Evaluation of degradation of coating

Table 3.2 Degree of Rusting and Rusted Area

Degree of Rusting	Rusted Areas (%)
Ri 0	0
Ri 1	0.05
Ri 2	0.5
Ri 3	1
Ri 4	8
Ri 5	40 to 50

※ Extracting from ISO 4628-3





Table 3.3 Degree of Rusting and Rusted Area on a Coating

Ri 1	Ri 2	Ri 3
		
Ri 4	Ri 5	
		

※ Extracting from ISO 4628-3

- Status of generation of rust on steel

Table 4.3 Reference photos of each rust grades of initial condition of uncoated substrate

Grade A	Grade B
	
Steel surface largely covered with adhering mill scale but little, if any, rust.	Steel surface which has begun to rust and from which the mill scale has begun to flake.
Grade C	Grade D
	
Steel surface on which the mill scale has rusted away or from which it can be scraped, but with slight pitting visible under normal vision.	Steel surface on which the mill scale has rusted away and on which general pitting is visible under normal vision.

※Extracting from ISO8501-1

➤ ISO8502-6,9 Extracting soluble salts using bresle sampler and analyzing conductivity

This Chloride Test on steel or Salt Test on steel using the Bresle Patch method will help to prevent coating failure due to salts such as chlorides and sulphates contaminating the surface prior to the coating application. This contamination can be tested quickly and simply using the Bresle Method to ensure the correct surface cleanliness.

Complying with International Standards: ISO 8502-6 and ISO 8502-9.





➤ Adhesion Test in compliance to ASTM D3359 Method A or Method B

These test methods are used to establish whether the adhesion of coating to a substrate is at a generally adequate level.

Test method A- An X-cut is made in the film to the substrate, pressure – sensitive tape is applied over the cut and then removed, and adhesion is assessed qualitatively on the 0 to 5 scale.

Test method B – A lattice pattern with either six or eleven cuts in each direction is made in the film to the substrate, pressure- sensitive tape is applied over the lattice and then removed, and adhesion is evaluated by comparison with descriptions and illustrations.

Test Method A is generally intended for use at job sites. Test method B is more suitable for use in laboratory. Also, Test method B is not considered suitable for films thicker than 5mils (125µm).

Surface of cross-cut area from which flaking has occurred. (Example for 6 parallel cuts)	None					Greater than 65%
Classification	5	4	3	2	1	0

5: The edges of the cuts are completely smooth; none of the squares of the lattice is detached.

4: Small flakes of the coating are detached at intersections; less than 5 % of the area is affected.

3: Small flakes of the coating are detached along edges and at intersections of cuts. The area affected is 5 to 15 % of the lattice.

2: The coating has flaked along the edges and on parts of the squares. The area affected is 15 to 35 % of the lattice.

1: The coating has flaked along the edges of cuts in large ribbons and whole squares have detached. The area affected is 35 to 65 % of the lattice.

0: Flaking and detachment worse than Grade 1.

Table 4.4 Measuring Adhesion by Tape Test Method A (X-cut)

Rating	Description
5A	No peeling or removal
4A	Trace peeling or removal along the incisions
3A	Jagged removal along the incisions up to 1/16 on either side
2A	Jagged removal along the incisions up to 1/8 on either side
1A	Removal of most of the coating from the area of the “X” under the tape
0A	Removal of coating beyond the area of the “X”

4.2 Standard Check Items after Surface Treatment

- Surface dust to be Tested after Dry-abrasive Blasting to comply ISO8502-3
- Surface Profile Test either via Needle Gauge or Text Test Tape suitable for required average Blast profile- ASTM D4417(method C), ISO 8503-5

4.3 Standard Check Items before Treatment

- ASTM F2420-05(2011) – Environment Test to be carried out – Relative humidity(RH) is on or below 85% & substrate temperature should be at least 3 centigrade higher than the dew point correspond to the prevailing RH at the time of application.
- Mix portion of paint shall be in accordance with data sheet.

4.4 Standard Check Items during Painting

- Application must be carried out with Wet Film Monitoring in compliance to ISO2808-7B and BS3900-C5-7
- Film thickness and spreading rate shall be in accordance with data sheet.
- Pot life of painting shall be in accordance with data sheet.
- Over-coating interval of painting shall be in accordance with data sheet.
- Curing time of painting shall be in accordance with data sheet.

4.5 Standard check Items after Painting

- Measurement of DFT to comply ISO19840 and SSPC PA2. SSPC – PA2 ISO 1416 : 1999(E)-3.4
Measurement of Dry Film thickness by digital / ultrasonic elecometer or similar instrument
- Pin hole / holiday / Misses identification test to be carried out internally to comply NACE
Standard SP 0188 and ISO 2960 : 2011& 2960 : 011 &ASTM – D4787

5. Recommended Substrate Conditions and Temperature

Substrate condition for painting shall be in accordance with data sheet.

General requirements for the painting are shown below.

- Maximum relative humidity during application and curing is 85%
- Do not apply during rain, fog or mist.
- During application and curing, a substrate temperature down to 5 centigrade is acceptable provided substrate is dry and free from ice
- Previous coat; dry and free from any contamination
- Substrate temperature should be at least 3 degree above dew point correspond to the prevailing RH at the time of application

6. Inspection Sheet and Repair Record

The result of zone painting shall be recorded. The record should include as-built drawings, inspection sheets, investigation reports, construction scene photograph, and method statement.

Inspection sheets are shown below.

Table 6.1 Inspection Sheet (1)

<u>PROJECT NAME</u>		
Client	:	
Consultant	:	
Contractor	:	
<u>INSPECTION OF MATERIAL</u>		
INSPECTION DATE	:	
STRUCTURE NAME	:	
Item	Description	
Area of Zone painting		
Surface preparation		
Date of painting		
Prime Coat		
1st Coat		
2nd Coat		
3rd Coat		
Note		
Photos	<u>Before Zone painting</u>	<u>After Zone painting</u>

Table 6.2 Inspection Sheet (2)

<u>PROJECT NAME</u>				
Client	:			
Consultant	:			
Contractor	:			
<u>INSPECTION OF MATERIAL</u>				
INSPECTION DATE	:			
STRUCTURE NAME	:			
Method of surface preparation				
Date of surface preparation				
Grade of surface preparation				
	Prime coat	1st	2nd	3rd
Contractor				
Supplier				
Name of painting				
Standard				
Color				
Date of painting				
Weather				
Temperature				
RH				
Status of existing paint				
Grade				
Equipment				
Cleaning the painting				
Name of painting				
Area of Zone painting (m ²)				
Method of painting				
Paint consumption (kg)				
Paint consumption (kg/m ²)				
Thickness (μm)				
Location of storage from previous painting				
Note				

Table 6.3 Inspection Sheet (3)

<u>PROJECT NAME</u>							
Client							
Consultant							
Contractor							
<u>INSPECTION OF MATERIAL</u>							
INSPECTION DATE							
STRUCTURE NAME							
1.General							
Item		Description					
Area of painting							
Date of measurement							
Standard total thickness of painting							
2.Measurment results of painting thickness							
Location of measurement		Thickness of painting					
		1	2	3	4	5	Average Xi
1							
2							
3							
4							
5							
6							
7							
8							
9							
Average value and Standard deviation		$\bar{X} = \frac{1}{N} \sum_{i=1}^N X_i = \mu\text{m}$ $s = \sqrt{\frac{1}{N-1} \sum_{i=1}^N (\bar{X} - X_i)^2} = \mu\text{m}$					
Management thickness		Average thickness μm Minimum thickness μm Standard deviation μm					

NOTE

- 1.Measurement location : 1nos / 10m²
- 2.Measurement number at 1 location : 5nos
- 3.Average thickness shall be thicker than 90% of targeted total thickness
- 4.Minimum thickness shall be thicker than 70% of targeted total thickness
- 5.Standard deviation shall be smaller than 20% of targeted total thickness
- If the average thickness is thicker than targeted total thickness , thickness of painting meet the requirement even standard deviation is bigger than 20% of targeted total thickness.
- 6.Measurement of film thickness shall be carry out after completion of painting

7. Health and Safety

7.1. Risk Assessment

The risk to health and safety from falling objects or defects in the structure shall be properly assessed. Platforms and temporary structures shall provide a stable and safe area to work. Do not take any unnecessary risks.

7.2 Personal Protection

Handling or processing cement products may generate dust which can cause mechanical irritation to the eyes, skin, nose and throat.

Appropriate eye protection shall be worn at all times while handling and mixing products.

Approved dust masks shall be worn to protect the nose and throat from dust.

Safety shoes, gloves and other appropriate skin protection shall be worn at all times.

Always wash hands with suitable soap after handling products and before food consumption

Table 7.1 Safety Equipment

Eye protection	Gloves	Helmet	Dust masks
			
Work wear	Safety shoes	Safety vest	Safety belt
			
Soundproofing earplugs			
			

7.3 First Aid

Seek immediate medical attention in the event of excessive inhalation, ingestion or eye contact causing irritation. Do not induce vomiting unless directed by medical personnel.

Flush eyes with plenty of clean water occasionally lifting upper and lower eyelids. Remove contact lenses immediately. Continue to rinse eye for 10 minutes and then seek medical attention. Rinse contaminated skin with plenty of water. Remove contaminated clothing and continue to rinse for 10 minutes and seek medical attention.

For detailed information refer to the material safety data sheet.

7.4. Traffic Control

If the repair work will be conducted under open traffic, the inspectors shall pay attention to provide safety for vehicles and pedestrians. Flagmen and safety cones must be placed to indicate the working site to vehicles /pedestrians. The work shall be done in compliance with all prevailing applicable Laws /regulations in Sri Lanka.

Appendix : Type of failure of painting

Table 1. Coating defects (1/2)





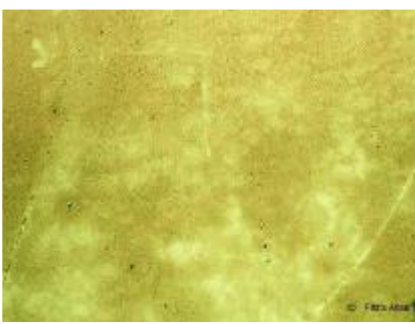

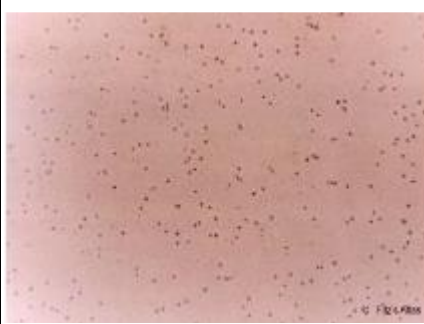
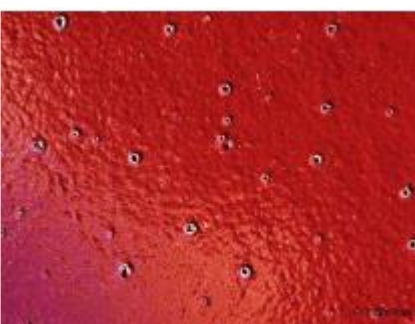




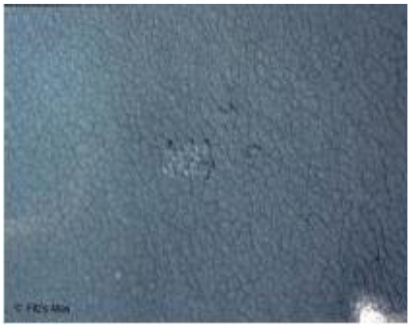







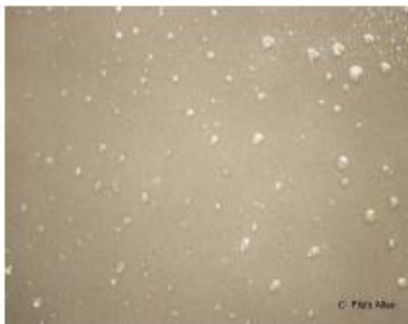

Adhesion	Alligatoring	Bleeding
		
Blistering	Bloom	Chalking
		
Cissing	Cratering	Delamination
		
Dry spray	Fading	Filiform
		

Table 2 Coating defects (2/2)

Mud Cracking	Orange Peel	Peeling
		
Pinhole	Runs	Rust Rash
		
Rust Spotting	Sagging	Solvent Popping
		
Wrinkling		
		








Attachment 4 - Machinery and Equipment for Repair Work

Table of Contents

1. Equipment for concrete repair work.....	1
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1. Equipment for concrete repair work

1.Surface preparation		
Power disc grinder	Air gun	Wire brush
		
High pressure water blasting	Electric wire brush	Electric cup wire brush
		
Scraper	Bristle Blaster	
		
2.Removing damaged concrete		
Electric pick hammer	Electric power chisel	Chisel
		
Power disc cutter	Electric drill with U shape bit	Concrete breaker
		









Concrete cutter	Handy concrete cutter	High pressure water blasting
		
Hammer		
		
3.Painting		
Brush	Brush roller	Spray gun
		



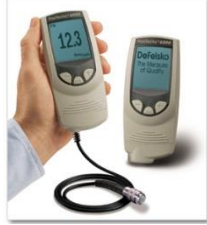






4.Mixing repair material		
Hand mixer	Concrete mixer	Grout mixer
		
Mortar mixer	Measure cup	Weight measuring apparatus
		
5.Setting repair material		
Air compressor	Caulking gun	Squeeze pump
		
Grout injection gun	Epoxy injection gun	Vibrator
		
Hopper	Wet spraying machine	Dry spraying machine
		

6.Setting repair material		
Wet spraying nozzle	Dry spraying nozzle	
		
7.Finishing		
Steel trowel	Panel for repair material	
		
8.Others		
Portable generator	High pressure water pump	Reinforcing steel cutter
		
Curing sheet	Pail can	Tape
		

2. Equipment for steel repair work

1.Surface preparation		
Power disc grinder	Air gun	Wire brush
		
High pressure water blasting	Electric wire brush	Electric cup wire brush
		
Scraper	Bristle Blaster	Needle hammer
		
2.Painting (Steel work)		
Woolen brush roller	Porous Brush roller	Spray gun
		
Brush	Roller bucket	
		

3.Mixing Paint (Steel work)		
Hand mixer	Bucket for paint	Measure cup
		
Weight measuring apparatus		
		
4.Steel process (Steel work)		
Gas cutter	Gas welding machine	
		
5.Bolting (Steel work)		
Torque wrench	Torque wrench	
		

6.Measuring instrument		
Temperature and relative humidity	Temperature of steel surface	Thickness of coating
		
7.Others		
Portable generator	High pressure water pump	Water tank
		
Curing sheet	Cloth	Tape
		

Attachment 5 - Outline of Representative in Depth Investigation

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1. Rebound Hammer Test

General investigation item	State of concrete
Information to be obtained	Strength of concrete
General	The test method is based on the principle that the rebound of an elastic mass (the hammer piston or impact plunger) depends on the hardness of the material it strikes, and the assumptions that the hardness is proportional to the materials strength and the material is homogenous. Rebound hammer test can only assess the compressive strength of the near surface layer of concrete in the zone of influence of hammer impact. It is useful in finding weak areas in concrete in a structure.

EquipmentDuring test

2. Carbonation Depth Measurement Test

General investigation item	State of concrete
Information to be obtained	Degree of penetration of deterioration factor (Depth of carbonation)
General	<p>Carbonation of concrete occurs when carbon dioxide, in the atmosphere in the presence of moisture, reacts with hydrated cement minerals to produce carbonates, e.g. calcium carbonate. The carbonation process is also called de-passivation. Carbonation penetrates below exposed surface of concrete extremely slow. The significance of carbonation is that the usual protection of reinforcing steel generally present in concrete due to the alkaline conditions caused by hydrated cement paste is neutralized by carbonation. Thus, if the entire concrete cover over the reinforcing steel is carbonated, corrosion of steel would occur if moisture and oxygen could reach the steel. The 1% Phenolphthalein Solution is made by dissolving 1gm of Phenolphthalein in 90 cc of ethanol. The solution is made up to 100 cc by adding distilled water. The pH value indicates if a solution is acid or alkaline, and therefore corrosion of reinforcing steel bars is determined if possible or not.</p> <p>pH < 7 : acid pH = 7 : neutral pH > 7 up to 14 : alkaline</p>
	
<u>Taking core</u>	<u>Core after testing</u>

3. Chloride penetration Depth Measurement Test

General investigation item	State of concrete
Information to be obtained	Degree of penetration of deterioration factor (Depth of chloride penetration)
General	<p>Chloride ions penetrate into concrete up to the surface of the reinforcing bars and destroying the passive-state film. When this destroyed film is subjected to oxygen and water, the reinforcing bars start to rust or begin to corrode. For chloride ions that penetrate into concrete, there are specifically two types of salinity: an internal salinity contained in sea sand, mixing water, etc., used during concrete production and an external salinity, such as seawater, seawater splash, blown-in salinity, spray from anti-freezing agents, etc., after concrete solidification.</p> <p>Taking core from existing structure and slicing it into 1 – 2cm thickness. After slicing the core, pulverization each specimen and measure the chloride ions by potentiometric titration.</p>
<div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">  <p><u>Equipment</u></p> </div> <div style="text-align: center;">  <p><u>Taking core</u></p> </div> </div>	





Slicing the core



Pulverization the core

4. Ultrasonic Pulse Velocity Test



General investigation item	State of concrete
Information to be obtained	Depth of crack, Delamination and internal voids
General	<p>A pulse of longitudinal vibrations is produced by an electro-acoustical transducer, which is held in contact with one surface of the concrete under test. When the pulse generated is transmitted into the concrete using a liquid coupling material such as grease or cellulose paste, it undergoes multiple reflections at the boundaries of the different material phases within the concrete. A complex system of stress waves develops, which include both longitudinal and shear waves, and propagates through the concrete. The first waves to reach the receiving transducer are the longitudinal waves, which are converted into an electrical signal by a second transducer. Electronic timing circuits enable the transit time "T" of the pulse to be measured.</p>
	
<u>Equipment</u>	<u>During test</u>

5. Rebar Detection Test (Magnetic Type)


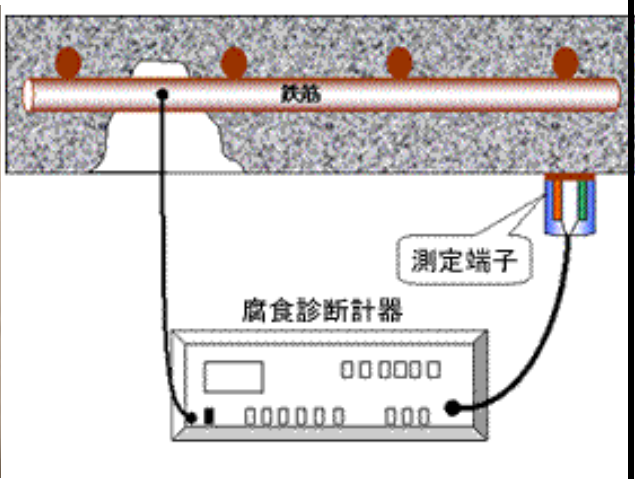
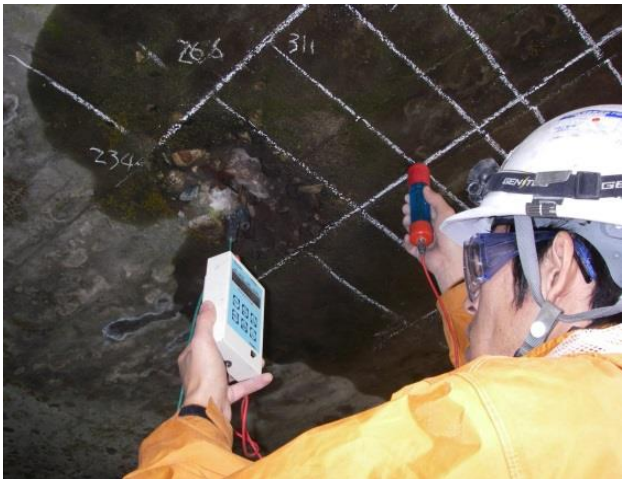

General investigation item	State of reinforcing steel
Information to be obtained	Location and diameter
General	<p>As a magnetic type scanning apparatus is turned on, it generates an electromagnetic field. When a reinforcing bar (rebar) or other metal object lies within this field, the lines of force become distorted. The disturbance caused by the presence of the metal in turn, produces a local change in field strength as detected by the search head and indicated by the meter. Both the orientation and proximity of the metal to the search head affect the meter reading. It is therefore possible to locate reinforcing bars and determine their orientation. Under ideal conditions, both bar size and cover can be estimated when neither is known. With apparatus using magnetic induction, a multi-coil search is used with a lower operating frequency than eddy current type. The principle used is similar to that of a transformer. Such instruments are less sensitive to non-magnetic materials than those using eddy current principle.</p>

EquipmentDuring test

6. Rebar Detection Test (Rader Type)

General investigation item	State of reinforcing steel
Information to be obtained	Location, diameter and cover
General	<p>Electromagnetic waves are transmitted from the antenna toward the concrete as shown in diagram below. The electromagnetic waves are reflected by an interface with the reflecting objects (e.g., reinforcing steel bars or cavities) whose electrical property is different from that of concrete. The waves are reflected back into the surface of concrete and received by the receiving antenna placed near the concrete surface. The distance to the reflecting objects can be calculated from the time the reflected waves need to reach the receiving antenna. The horizontal locations of the objects can be detected by moving the main unit on the surface of concrete. Since this radar is designed to probe objects with high resolution that are near from the surface of concrete, it transmits pulse waves having a width of only about one nanosecond (one-billionth of a second) or less.</p>
<div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">  <p><u>Equipment</u></p> </div> <div style="text-align: center;">  <p><u>During test</u></p> </div> </div>	

7. Half-Cell Electric Potential Test

General investigation item	State of reinforcing steel
Information to be obtained	State of steel corrosion embedded in concrete
General	<p>The corrosion (rusting) of steel rebar is an electro-chemical process, involving anodic (corroding) and cathodic (passive) areas of the metal. By measuring concrete-surface electrical potentials relative to a standard reference electrode on a pre-defined grid, the presence and location of corrosion and its probable future performance may be assessed. To use this technique, it is necessary that a continuous electrical current is present in the reinforcing bars (this is normally achieved with a metal wire connecting the various reinforcing element, for example horizontal and vertical bars). A multi meter can be used to check that this electric current exists.</p>
<div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">  <p><u>Equipment</u></p> </div> <div style="text-align: center;">  <p><u>During test</u></p> </div> </div>	
<div style="display: flex; justify-content: space-around;"> <div style="text-align: center;">  <p><u>During test</u></p> </div> <div style="text-align: center;">  <p><u>During test</u></p> </div> </div>	

8. Metal Thickness Test

(Ultrasonic nondestructive test / Depth gauge / Micro meter)

General investigation item	State of steel
Information to be obtained	Thickness of steel member
General	<p>This ultrasonic nondestructive testing is used in characterizing material thickness, integrity, or other physical properties by means of high-frequency sound waves. It has become a widely used technique for quality control. In thickness gauging, ultrasonic techniques permit quick and reliable measurement of thickness without requiring access to both sides of a part. Accuracies as high as ± 1 micron or ± 0.0001 inch are achievable in some applications. Precision ultrasonic thickness gauges usually operate at frequencies between 500 KHz and 100 MHz, using piezoelectric transducers to generate bursts of sound waves when excited by electrical pulses. Typically, lower frequencies will be used to optimize penetration when measuring thick, highly attenuating, or highly scattering materials, while higher frequencies will be recommended to optimize resolution in thinner, non-attenuating, non-scattering materials. A pulse-echo ultrasonic thickness gauge determines the thickness of a part or structure by accurately measuring the time required for a short ultrasonic pulse generated by a transducer to travel through the thickness of the material, reflect from the back or inside surface, and be returned to the transducer. In most applications this time interval is only a few microseconds or less. The measured two-way transit time is divided by two to account for the down-and-back travel path, and then multiplied by the velocity of sound in the test material. The result is expressed in the well-known relationship:</p>



During test using Depth gauge



During test using Micro meter



Equipment (Ultrasonic gauge)



During test using Ultrasonic gauge